



## MEMORANDUM

TO: Jim Eddinger, U.S. Environmental Protection Agency, OAQPS (C439-01)

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SUBJECT: Development of Model Units for the Industrial/Commercial/Institutional Boilers and Process Heaters National Emission Standards for Hazardous Air Pollutants

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### 1.0 INTRODUCTION

This memorandum describes the development of model units for the Industrial/Commercial/Institutional Boiler and Process Heater NESHAP. Model units were created to represent approximately 58,500 combustion units in the boiler and process heater major source population database so that an impacts analysis could be performed on a reasonable number of units and could be conducted in a practical and timely manner. Additionally, complete characterization information was not available for every boiler and process heater in the database. The development of model units involved reviewing parameters that distinguish and characterize each unit, such as the materials combusted and heat input capacity (in million British thermal units per hour (MMBtu/hr)). Model units were defined based on various combinations of the parameters so that the boiler and process heater population would be accurately represented by the models.

Section 2.0 of this memorandum discusses the procedures used to develop general model units. Section 3.0 describes additional parameters developed to define general model units. Section 4.0 describes the development of specific model units with control device levels from the general model units. Section 5.0 discusses the distribution of boilers and process heaters into

control level model units for the purpose of totaling the number of boilers and process heaters per model unit for the impacts analysis.

## **2.0 DEVELOPMENT OF GENERAL MODEL UNITS**

General model units were developed from basic information (excluding control device information) that was available for the majority of boilers and process heaters in the population database and was determined to be necessary in characterizing and distinguishing each model unit. The basic information includes heat input capacity, materials burned, and combustor design.

The formation of the population database is described in the memorandum *Development of the Population Database for the Industrial/Commercial/Institutional Boilers and Process Heaters National Emission Standards for Hazardous Air Pollutants*.<sup>1</sup> The population database was created using the Industrial Combustion Coordinated Rulemaking (ICCR) Inventory version 4.1 and Survey version 3.0 databases. Descriptions of tables and fields in the population database can be found in the memoranda *Description of the ICCR Inventory Database, Versions 4.0 and 4.1*<sup>2</sup> and *Description of Fields in the ICCR Survey Database Version 3.0*.<sup>3</sup>

### **2.1 Model Unit Material Combinations**

This section describes the creation and refinement of model unit material combinations and assumptions used to assign the material combinations to boilers and process heaters in the population database.

#### **2.1.1 Creation of Model Unit Material Combinations**

The population database indicates that approximately 65 different fuels in various combinations are combusted by boilers and process heaters. The different fuels were grouped into a smaller number of material categories in order to estimate impacts on a more manageable number of model units and because adequate information was not available for all fuels. All existing fuels were reviewed and standardized into eight material categories: coal, gas, liquid fossil fuel (including waste oil), non-fossil liquid, non-fossil solid, bagasse, other biomass, and wood. For example, anthracite coal, bituminous coal, sub-bituminous coal, lignite coal, waste

coals, petroleum coke, and peat were all identified as “coal”. Similarly, tires, construction derived waste, plastics, refuse derived fuel, and industrial solid waste were all identified as “non-fossil solid”. Table 2-1 presents how the original fuels identified in the population database are associated with the seven material categories.

**Table 2-1. Correlation of Database Fuels to Seven Material Categories**

<b>Fuel in Population Database</b>	<b>Material Category</b>
Anthracite Coal	Coal
Anthracite Waste Coal (culm)	
Bituminous Coal	
Bituminous Waste Coal (gob)	
Coal	
Lignite Coal	
Peat	
Petroleum Coke	
Sub-bituminous Coal	
Biogas (includes sewage digester gas)	Gas
Blast Furnace Gas	
Butane	
Carbon Monoxide Gas	
Coke Oven Gas	
Hydrogen	
Landfill Gas	
Liquified Petroleum Gas	
Natural Gas	
Other Gas	
Petrochemical Process Gas	
Petroleum Refining Process Gas	
Process Coproduct Gas	
Process Gas Unspecified	
Propane	

**Table 2-1. Correlation of Database Fuels to Seven Material Categories (Continued)**

<b>Fuel in Population Database</b>	<b>Material Category</b>
Crude Oil	Liquid Fossil Fuel
Diesel Fuel	
JP-8 Aviation Fuel	
No. 2 Distillate Oil	
No. 4 Fuel Oil	
No. 5 Fuel Oil	
No. 6 Residual Oil	
Oil	
Waste Oil	
Aqueous Waste	Non-fossil Liquid
Liquid Waste	
Other Liquid	
Process Coproduct Liquid	
Construction Derived Waste	Non-fossil Solid
Decorative Laminate/Cast Polymer Scrap	
Industrial Sludge	
Industrial Solid Waste (non-hazardous)	
Industrial Wastewater Sludge	
Municipal/Commercial Solid Waste: Type 0 - Trash	
Municipal/Commercial Solid Waste: Type 2 - Refuse	
Municipal/Commercial Solid Waste: Type 3 - Garbage	
Other Solid	
Plastics	
Process Coproduct Solid	
Process Engineered Fuels	
Refuse Derived Fuel	
Tires	
Agricultural Waste	Other Biomass
Bagasse	Bagasse

**Table 2-1. Correlation of Database Fuels to Seven Material Categories (Continued)**

<b>Fuel in Population Database</b>	<b>Material Category</b>
Adulterated Coproduct: Other Wood	Wood
Adulterated Coproduct: Plywood/Particle board/Finished	
Adulterated Coproduct: Treated	
Dried Milled Lumber	
Timber: Little Bark	
Timber: Mostly Bark	
Timber: Whole Tree	
Sawdust	
Wood Composed of > 20% Sander Dust	
Wood Unspecified	

Once these 8 material categories had been created, 18 material combinations were created from them to represent the existing fuel type combinations (for example, bituminous coal, residual fuel oil, and natural gas; or sawdust and waste oil) in the population database. The 18 material combinations were:

- coal;
- wood;
- other biomass;
- bagasse;
- gas;
- distillate liquid fossil fuel;
- residual liquid fossil fuel;
- non-fossil liquid/non-fossil solid;
- coal/wood;
- coal/wood/non-fossil liquid/non-fossil solid;
- wood/non-fossil liquid/non-fossil solid;
- wood/other biomass/non-fossil liquid/non-fossil solid;
- wood/other biomass/liquid fossil fuel;

- gas/liquid fossil fuel;
- gas/non-fossil liquid/non-fossil solid;
- gas/wood;
- gas/other biomass; and
- liquid fossil fuel/non-fossil liquid/non-fossil solid.

Telephone contacts<sup>4</sup> and review of database information indicated that boilers burning natural gas and/or liquid fossil fuels in small quantities in combination with coal, wood, or non-fossil materials are using the gas and/or liquid fossil fuel as startup, backup, or supplemental fuel only. Therefore, the gas and/or liquid fossil fuel was considered to be insignificant when developing unique model unit material combinations for these types of boilers.

Boilers and process heaters were assigned one of the 18 material combinations using the fuel data available in the population database. For example, a boiler combusting natural gas and bagasse would be identified as “bagasse”. Similarly, a boiler combusting bituminous coal and dried milled lumber would be identified as “coal/wood”. In addition, based on the assumption concerning small quantities of gas and/or liquid fossil fuel, a boiler combusting bituminous coal, dried milled lumber, and natural gas would also be identified as “coal/wood”.

Material combinations that include “non-fossil liquid/non-fossil solid” were assigned to units that fire either of these materials or a combination of both. For example, a boiler which burns coal, wood, and a process liquid; a boiler which burns coal, wood, and sludge; and a boiler which burns coal, wood, liquid waste, and industrial solid waste would all be assigned the “coal/wood/non-fossil liquid/non-fossil solid” material combination.

### **2.1.2 Refinement of Model Unit Material Combinations**

Emission factors in lb/MMBtu were developed from data in the boiler emissions test database, which was developed from the ICCR Emissions Test Database version 5.0.<sup>5,6,7</sup> A review of the emission factor data for fuel types corresponding to the 18 material combinations indicated that some model unit material combinations would need to be combined in order for each model unit to have adequate emission factor data to complete the impacts analysis. For example, “coal/wood” and “coal/wood/non-fossil liquid/non-fossil solid” were combined because the latter material combination did not have an adequate number of emission factor data

points in the boiler emissions test database. Because non-fossil materials in the existing population were co-fired at very low percentages, the combination of model units involving non-fossil fuels is expected to have no effect on the representativeness of the emission factors. The material combination “coal/wood/non-fossil liquid/non-fossil solid” now includes units that combust only coal and wood; coal, wood, and a non-fossil liquid; coal, wood, and a non-fossil solid; or coal, wood, a non-fossil liquid, and a non-fossil solid. Similarly, “gas/liquid fossil fuel”, “gas/wood”, and “gas/other biomass” were combined into one material combination. The 18 material combinations were combined in this manner to create 10 final model unit material combinations:

- coal;
- coal/wood/non-fossil liquid/non-fossil solid;
- gas;
- gas/wood/other biomass/liquid fossil fuel;
- distillate liquid fossil fuel;
- residual liquid fossil fuel;
- non-fossil liquid/non-fossil solid/gas;
- wood;
- wood/other biomass/non-fossil liquid/non-fossil solid; and
- bagasse/other.

### **2.1.3 Procedures and Assumptions in Assigning Model Unit Material Combinations**

The population database is comprised of two separate databases, the Survey database (which contains information on units burning non-fossil fuels) and the Inventory database (which contains mostly information on units burning fossil fuels). For those units in the Survey component of the population database, the material code and % annual input data provided by ICR respondents were used to determine fuel types and material combinations. The basis for determining fuel types for boilers and process heaters in the Inventory component of the population database was the Source Classification Code (SCC) description. The Inventory component also includes a “Fuel Type” field which is populated approximately 30% of the time for boilers and often includes extraneous information instead of actual fuel data. In contrast, the

fuel data provided in the SCC description are available for all boilers and process heaters because at least one SCC is associated with each combustion unit. In addition, the “Fuel Type from SCC” field contains standardized fuel codes. Therefore, the “Fuel Type from SCC” field was used to assign material combinations to those boilers and process heaters in the Inventory component of the population database.

There are 273 boilers in the population database for which fuel data are not available. Therefore, fuel data for approximately 42,950 boilers were considered in creating model unit material combinations. Because they comprise such a small percentage of the total population, the boilers without fuel data were not used in subsequent analyses. There are 1,140 process heaters in the population database for which fuel data are not available, and therefore could not be assigned a model unit material combination. Section 5.3 describes how these process heaters without fuel data were handled in subsequent analyses.

There were three exceptions to the procedure of assigning boilers in the population database a material combination based on data in the “Fuel Type from SCC” field. First, for boilers in the Inventory component of the population database with SCC descriptions that indicate that they are coal- or oil-fired, the combustor descriptions were reviewed to determine if the boilers actually burn a different type of fuel. This review was done to verify an analysis comparing fuel usage reported in Department of Energy (DOE) reports to values from the population database which indicated that some revisions needed to be made to the population database.<sup>1</sup> Boilers which were determined through this review to burn only gas were reassigned the “gas” material combination. The review also indicated that a few boilers which were initially indicated to be coal boilers by the SCC description were actually liquid fossil fuel boilers and were reassigned a different model unit material combination accordingly. These changes are based on the assumption that a combustor description is facility-specific information provided by the facility and would therefore be more accurate than the SCC description.

Boilers in the Inventory component of the population database with SCC descriptions that indicate that they combust a combination of distillate fuel oil and natural gas were assumed to predominantly fire natural gas. This assumption is based on distillate fuel oil being more expensive than natural gas and distillate fuel oil typically being used only as a supplemental or startup fuel, rather than a primary fuel. Therefore, all of the boilers that were indicated to burn only a combination of distillate fuel oil and natural gas were assigned the “gas” material



combination instead of the “distillate liquid fossil fuel” material combination. This assumption did not apply to boilers that combust any type of gas other than natural gas in conjunction with distillate fuel oil. For example, a boiler which combusts process gas and distillate fuel oil was not reassigned the “gas” material combination. The assumption would not be valid for this type of boiler because a facility might not have the ability or the capacity to fire as much process gas as needed to operate the boiler.

Boilers in the Inventory component of the population database with SCC descriptions that indicate that they combust a combination of residual fuel oil and natural gas were assumed to predominantly fire natural gas. This assumption is based on residual fuel oil being more difficult to burn than natural gas and natural gas often being a cheaper and easier option if a combustion unit has the ability to burn natural gas. This assumption did not apply to boilers that combust any type of gas other than natural gas in conjunction with residual fuel oil. This assumption also did not apply for the few boilers which fire a combination of natural gas and residual fuel oil and have an add-on air pollution control device. It was assumed that if a natural gas/residual fuel oil boiler has an add-on control device for metals and/or particulate matter, the boiler is probably predominantly firing residual fuel oil. All of the boilers that were indicated as burning a combination of residual fuel oil and natural gas, and were not identified as having an add-on control device, were assigned the “gas” material combination instead of the “residual liquid fossil fuel” material combination.

## **2.2 Model Unit Combustor Designs**

Boiler design information in the population database was reviewed to determine model unit combustor designs. For boilers in the Inventory component of the population database, combustor design information is provided in the SCC description. Approximately 60 SCC descriptions which pertain to boilers indicate a design type of pulverized coal, stoker, or fluidized bed, while the remaining boiler SCC descriptions do not indicate a design type. Boiler design data in the Survey component of the population database are based on check box responses from an ICCR Information Collection Request (ICR) Questionnaire. Respondents could check as many design descriptions as applied to their boilers, from a list provided in the questionnaire. The list is presented in Appendix A.

Boilers in the population database were initially grouped into four categories based on combustor design: wall-fired/pulverized coal (including cyclone-fired); stoker/dutch oven; fluidized bed; and other. Boilers were divided into these categories so any potential differences in emissions, size ranges, and other parameters could be evaluated. Any boilers in the population database for which there was not specific combustor design information available were distributed among the design types according to the existing distribution of the known population.

Review of the information available to develop emission factors for model units indicated that emissions data availability was very limited for each of the four combustor design categories. Additionally, emission characteristics (for example, type of pollutant) were determined to be more influenced by the type of fuel burned rather than the combustor type. Information required to be input into costing algorithms (for example, pollutant loading, flue gas flow rate, temperature, and moisture content) were also very limited for all four combustor design categories. The data that were available did not show appreciable differences in emissions between combustor types. Consequently, combustor design categories were combined to provide a large pool of emission factors and cost algorithm inputs for the impacts analysis. While some small variations in the emissions and cost inputs exist for different combustor types, these differences were not considered significant, particularly when compared to the effects of fuel type and combustor heat input parameters.

One exception was made to the combination of combustor types in the development of model units. The wall-fired/pulverized coal combustor type for wood and coal boilers was kept separate from the fluidized bed combustor type because it was thought that fuel switching could be done more economically on wall-fired/pulverized coal boilers. However, the differences in combustor type could not be incorporated into the fuel-switching impacts analysis. It is expected that such differences in combustor type would be insignificant to costs when compared to other factors, such as the cost of fuel. Therefore, the separate model units made for coal and wood “wall-fired/pulverized coal” combustors could be combined back with all the other models. These coal and wood model units were not actually recombined, but the same emission factors and cost input parameters were used in the impacts analysis for both combustor types.

Most process heaters are gas- or liquid-fired, and were assigned to the appropriate model unit without considering any combustor design differences. However, a few heaters do use wood

as a fuel. These heaters were assigned to the wood model units that include the “Other” combustor design type, although the emission factors and other parameters are not distinguished according to combustor design.

## **2.3 Model Unit Capacity Ranges**

This section describes the creation and refinement of general model unit capacity ranges and assumptions used to assign model unit capacity ranges to the boilers and process heaters in the population database.

### **2.3.1 Creation of Model Unit Capacity Ranges**

For the impacts analysis, model unit capacity ranges were determined based on review of available capacity data in the population database as well as a review of the New Source Performance Standard (NSPS) for industrial, commercial, and institutional boilers, which has four capacity ranges: 0-10, 10-100, 100-250, and >250 MMBtu/hr. To be consistent with the NSPS, the same four capacity ranges were used in this analysis. The SCC description in the Inventory component of the population database often indicates capacity range data of “< 10 Million Btu/hr” or “10-100 Million Btu/hr”, which integrates well with these four capacity ranges.

Capacity data in the Inventory component of the population database are contained in the fields “Capacity”, “Capacity Units”, and “Capacity Range”. The “Capacity” field contains numerical capacity data and the “Capacity Units” field provides the corresponding units of measure for these numerical data. The “Capacity Range” field contains information included in the SCC description, such as “10-100 Million Btu/hr”, which would indicate that the unit has a capacity in the range of 10-100 MMBtu/hr, although the actual value is not reported in the SCC description. The numerical capacity data were assumed to be more accurate than the capacity range data from the SCC description because the numerical data would have been expressly indicated by each facility for inclusion in the original data source. Approximately 40% of boilers in the Inventory component of the population database do not have numerical capacity data in units of MMBtu/hr. For the boilers with no numerical capacity data at all or with numerical capacity data in units other than MMBtu/hr, data from the “Capacity Range” field which indicated “< 10 Million Btu/hr” or “10-100 Million Btu/hr” were used to determine which model

unit capacity range to assign to the boilers, even though exact capacity values were not known. Having model unit capacity ranges of 0-10 and 10-100 MMBtu/hr allowed approximately 9,900 additional boilers to be assigned model unit capacity ranges, based on available SCC description capacity range data.

### **2.3.2 Assignment of Model Unit Capacity Ranges to Boilers**

Boilers Originating from ICCR Inventory Database. Numerical capacity data in the Inventory and Survey components of the population database are available in approximately 55 different units of measure. Review of capacity data for boilers in the Inventory component determined that approximately 90% of the boilers with the “Capacity” field populated had capacity values in units of MMBtu/hr, the preferred units of measure. These actual capacity values were used to assign one of the four model unit capacity ranges to each boiler. Of the remaining boilers with capacity data in units other than MMBtu/hr plus the boilers without capacity data, about 60% had a capacity range from the SCC description of either “< 10 MMBtu/hr” or “10-100 MMBtu/hr”. These capacity range data in the SCC description were used to assign a model unit capacity range of 0-10 or 10-100 MMBtu/hr to these boilers. Section 5.1 describes how boilers that could not be assigned a model unit capacity range were incorporated into the model units.

Boilers Originating from ICCR Survey Database. Review of capacity data for boilers in the Survey component determined that approximately 70% of the boilers with a capacity field populated had capacity values in units of MMBtu/hr. For those boilers with capacity values in units of measure other than MMBtu/hr, the capacities were converted into units of MMBtu/hr whenever possible. Units of measure that were converted to MMBtu/hr include: 1000 lb of steam/hr; lb of steam/hr; gallon/minute of number 2 fuel oil; ton/day of wood; lb/hr of wood; ton/year of wood; ton/hour of wood; horsepower; and kilowatts. Appendix B provides the equations used to convert these units of measure to MMBtu/hr and also references the sources of conversion constants used in the equations. The conversion of capacity data from other units of measure to MMBtu/hr allowed an additional 29% of boilers from the Survey database to be assigned a model unit capacity range. Section 5.1 describes how boilers that could not be assigned a model unit capacity range were incorporated into the model units.

### **2.3.3 Revision of Model Unit Capacity Range Assignments for Certain Boilers**

For boilers that either originally had capacity data in MMBtu/hr or whose capacity values had been converted into MMBtu/hr, the capacity values ranged from .0001 to 14,646,000 MMBtu/hr. Capacity values above 1,300 MMBtu/hr in the Inventory component of the population database were not used in calculating model unit average capacities, based on the typical range of actual capacities for industrial, commercial, and institutional boilers. However, these boilers were not removed from the population database and were included in all subsequent analyses based on the population database. Section 5.1 discusses how these boilers were incorporated into the model units.

Capacity values above 1,300 MMBtu/hr which originated from the ICCR Survey database were reviewed to determine if an ICR respondent had misinterpreted the question relating to capacity, such as entering 1,000,000 on the survey form in the box for MMBtu/hr, instead of 1 MMBtu/hr. This review also identified some data entry errors, such as entering 8,350 in the Survey database when 83.50 was entered in the box for MMBtu/hr on the survey form. Based on this review, a few of the capacity values greater than 1,300 MMBtu/hr were revised to lower capacities. The corrected capacity values were used to assign model capacity ranges to these few boilers and were used in calculating model unit average capacities. Those boilers in the Survey component with capacity values greater than 1,300 MMBtu/hr that could not be resolved were not removed from the population database and the boilers were used in all subsequent analyses based on the population database. However, their capacities were not used in the calculation of model unit average capacities. Section 5.1 discusses how these boilers were incorporated into the model units.

### **2.3.4 Assignment of Model Unit Capacity Ranges to Process Heaters**

Capacity data for indirect-fired process heaters were analyzed during the development of an EPA process heater database. Capacity data in units of MMBtu/hr were retained and capacity data in other units of measure were converted to units of MMBtu/hr, when possible. Further information concerning the review and conversion of process heater capacity data is provided in the memorandum *Emissions of Hazardous Air Pollutants From Process Heaters at Major and Area Sources*.<sup>8</sup> Initially, capacity range information provided in the SCC description was not considered. But for the purpose of assigning model unit capacity ranges to process heaters in the

population database, the “Capacity Range” field in the Inventory component was reviewed for those process heaters without numerical capacity data in MMBtu/hr. These capacity range data, along with the numerical capacity data originally provided in the EPA process heater database, were used to assign model unit capacity ranges to process heaters in the population database, in the same manner as for boilers. Of the 14,108 process heaters in the population database that were assigned a model unit material combination, 5,934 process heaters do not have numerical capacity data in MMBtu/hr or capacity range data from the SCC. Section 5.4 discusses how these process heaters were incorporated into the model units.

## **2.4 Limited Use Units**

A review of the information available for boilers shows that a number of units are back-up, emergency, or peaking units that operate infrequently. Back-up or emergency units only operate if another boiler that is the regular source of energy or steam is not operating (for example, during shutdown for maintenance and repair). Peaking units operate only during peak energy use periods, typically in the summer months. The population database indicates that these infrequently-operated units typically operate 10 percent of the year or less. These limited use units, when called upon to operate, must respond without failure and without lengthy periods of start-up. As such, their use and operation are different than those of typical industrial, commercial, and institutional boilers. Consequently, separate model units were created to represent these limited use units.

The population database was reviewed to identify which non-limited use model units had been assigned combustion units that were considered limited use. A total of 35 model units were identified, resulting in 35 additional model units being created to represent limited use units. The non-limited use and limited use units have the same basic model characteristics, so the model unit parameters for the non-limited use units were also used for the limited use units. Table 3-1 and Appendix D include the limited use model units (model numbers 47 through 83) and their model unit parameters.

Limited use boilers and process heaters in the Inventory and Survey components of the population database were mostly identified by reviewing the hours of operation per year data. Boilers and heaters that were indicated to operate less than 876 hours per year (which is 10% of the total number of hours in a year) were flagged as being limited-use. In addition, combustor

description information was searched for keywords such as “stand-by”, “emergency”, and “auxiliary” to determine additional limited-use units.

### **3.0 ADDITIONAL PARAMETERS WHICH DEFINE MODEL UNITS**

In order to perform emissions and costs analyses, additional model unit parameters, such as average capacity, annual capacity factor, exhaust air temperature, exhaust flowrate, and exhaust moisture content, were developed. This section discusses the development of these types of model unit parameters.

#### **3.1 Average Capacity**

Average capacities for each model unit were calculated from capacity data in units of MMBtu/hr in the population database. For those boilers in the Inventory component of the population database that do not have numerical capacity data in MMBtu/hr, but have capacity range data in MMBtu/hr from the SCC description, a capacity value was calculated using boiler distribution information from a previous EPA report.<sup>9</sup>

The EPA report, Population and Characteristics of Industrial/Commercial Boilers in the U.S.<sup>9</sup>, provides a distribution of the national boiler population of coal, oil, and natural gas boilers with capacities between 0 and 100 MMBtu/hr. This distribution of boilers is provided for intermediate capacity ranges of: 0-0.4; 0.4-1.5; 1.5-10; 10-25; 25-50; and 50-100 MMBtu/hr. The mid-point values of the capacity ranges were assigned to those boilers with SCC capacity range data of 0-10 or 10-100 MMBtu/hr only. For example, the report<sup>9</sup> indicated that for gas boilers between 0-10 MMBtu/hr, 56% are between 0-0.4 MMBtu/hr, 33% are between 0.4-1.5 MMBtu/hr, and 11% are between 1.5-10 MMBtu/hr. Therefore, out of an approximate 2,400 gas boilers with the capacity range 0-10 MMBtu/hr in the population database, 1,344 boilers would be assumed to have a capacity of 0.2 MMBtu/hr, the midpoint of the 0-0.4 MMBtu/hr range. Likewise, 792 gas boilers would be assumed to be 0.95 MMBtu/hr and 264 would be assumed to be 5.75 MMBtu/hr. This method gives average capacity results more representative of the national boiler population capacity distribution than a method which assumes that all 2,400 gas boilers have a capacity value of 5 MMBtu/hr, the midpoint of the 0-10 MMBtu/hr range. Coal and fuel oil boilers with SCC capacity range data were handled in the same manner as the gas

boilers. The distribution for fuel oil boilers was used for both residual and distillate fuel oil boilers.

The calculated capacities based on SCC capacity ranges were averaged with the real boiler capacity data in MMBtu/hr to calculate average capacities for the model units. The boiler population report<sup>9</sup> does not provide distribution data for non-fossil boilers. Therefore, for model units with fuel types other than “gas”, “coal”, “distillate liquid fossil fuel”, and “residual liquid fossil fuel”, the average capacities were calculated using only the actual capacity data available in the population database. The majority of information on wood and non-fossil boilers was provided in the Survey component of the population database, which has more complete capacity data.

### **3.2 Average Annual Capacity Factor**

Average annual capacity factors (percent of rated design heat input capacity) were calculated from available capacity utilization data in the population database. The Survey component of the population database contains a “Typical Operating Rate” field populated from ICR questionnaire responses. Respondents indicated if the typical operating rate of their combustion unit, expressed as percent of rated design capacity, was in one of the following ranges: “0-20”, “20-40”, “40-60”, “60-80”, “80-100”, or “>100”. Of the boilers in the Survey component of the population database which had been assigned to a model unit, 97% had typical operating rate data. In the Inventory component of the population database, operating rate data in units of percent capacity were available for only approximately 150 boilers. These boilers were assigned a corresponding capacity utilization range from the Survey database (for example, an operating rate of 70 percent of capacity was assigned the range “60-80”).

An average capacity factor, weighted by the number of boilers in each capacity utilization range, was calculated for each model unit. The midpoint of each boiler’s range was used as the boiler’s capacity utilization value. For example, if 50 boilers assigned to a given model unit had the capacity utilization range of “40-60%”, 20 boilers had “60-80%”, and 10 boilers had “80-100%”, then the weighted average annual capacity factor for that model unit would be 60 percent of rated design capacity.



For model units that did not have any assigned boilers with available capacity utilization data, an average annual capacity factor was assigned based on the factor for a similar model unit. For example, for the model unit defined by “coal”, “wall-fired/pc”, and “0-10 MMBtu/hr”, an average annual capacity factor of 70% was assigned, based on the calculated average annual capacity factor of 70% for the model unit defined by “coal”, “fluidized bed/stoker/do/other”, and “0-10 MMBtu/hr”. A subsequent analysis comparing fuel usage reported in Department of Energy (DOE) reports to values from the population database indicated that some revisions needed to be made to the population database and typical capacity utilizations.<sup>1</sup> As a result of the revisions, an average annual capacity factor of 60% was assigned to all coal, distillate, and residual fossil fuel model units.

### **3.3 Excess Air and Exhaust Temperature**

Information concerning excess air (in percent) and exhaust temperature (in degrees Fahrenheit (F)) was reviewed in two EPA publications on fossil fuel industrial boilers<sup>10</sup> and non-fossil fuel industrial boilers.<sup>11</sup> Based on review of these documents, gas and distillate oil model units were assigned a typical excess air value of 15% and an exhaust temperature of 350 degrees F. Residual oil model units were assigned a typical excess air value of 15% and an exhaust temperature of 400 degrees F. Coal model units less than 400 MMBtu/hr were assigned a typical excess air value of 50% and an exhaust temperature of 400 degrees F. Coal model units greater than 400 MMBtu/hr were assigned a typical excess air value of 30% and an exhaust temperature of 400 degrees F. Model units with non-fossil material combinations were assigned a typical excess air value of 50% and an exhaust temperature of 400 degrees F.

### **3.4 Exhaust Flowrate, Moisture and Percent Oxygen**

Information on exhaust gas flowrate, moisture content, and percent Oxygen for boilers and process heaters are limited, and in most cases, not available. Therefore, these parameters were calculated from the combustion kinetics of burning the primary fuels. For this calculation, the Hydrogen, Carbon, Nitrogen, Oxygen, and water composition of the primary fuel is necessary.

For model units with material combinations which are not “coal”, “gas”, “distillate liquid fossil fuel”, “residual liquid fossil fuel”, or “wood”, the fuel use data in the population database

were used to determine the material(s) that best represents the material combination. For example, for the material combination “coal/wood/non-fossil liquid/non-fossil solid”, a combination of 50% coal and 50% wood was determined to be most representative. For the material combinations “gas/wood/other biomass/liquid fossil fuel” and “wood/other biomass/non-fossil liquid/non-fossil solid”, a fuel type of 100% wood was determined to be most representative. Representative materials were determined by reviewing fuel data in the population database for all the units assigned these material combinations. For the material combination “non-fossil liquid/non-fossil solid/gas”, the exhaust flowrate was estimated by using the highest flowrate calculated for the typical fuels included in this material combination.

### **3.4.1 Exhaust Flowrate, Moisture and Percent Oxygen for Gas Model Units**

Natural gas average material analysis data (in percent by weight) were obtained for Hydrogen, Carbon, Nitrogen, and Oxygen.<sup>12</sup> These average percentages and the elements’ molecular weights were used to calculate the theoretical amount of Oxygen (in moles per hundred pounds of fuel (mole/100 lb fuel)) necessary for the combustion of natural gas. An average heating value in Btu/lb for natural gas was also obtained.<sup>12</sup> The ratio of Nitrogen to Oxygen in the atmosphere, the average heating value for natural gas, and the excess air percentage and exhaust temperature (discussed in Section 3.3) for gas model units were used to calculate the exhaust flowrate (actual cubic feet per minute (acfm)), exhaust moisture content (%), and exhaust Oxygen content (% dry) for gas model units. An example calculation is provided in Appendix C.

### **3.4.2 Exhaust Flowrate, Moisture and Percent Oxygen for Wood Model Units**

Wood average material analysis data (in percent by weight) were obtained for Hydrogen, Carbon, Water, Nitrogen, Oxygen, and Ash.<sup>11</sup> The average percentages for Hydrogen, Carbon, Nitrogen, and Oxygen, in addition to the molecular weights for these elements, were used to calculate the theoretical amount of Oxygen (mole/100 lb fuel) necessary for the combustion of wood. An average heating value in Btu/lb for wood was also obtained.<sup>11</sup> The ratio of Nitrogen to Oxygen in the atmosphere, the average heating value for wood, and the excess air percentage and exhaust temperature (discussed in Section 3.3) for wood model units were used to calculate the exhaust flowrate (acfm), exhaust moisture content (%), and exhaust Oxygen content (% dry) for

wood model units. These parameters were also applied to model units with “gas/wood/other biomass/liquid fossil fuel” and “wood/other biomass/non-fossil liquid/non-fossil solid” material combinations, because wood was determined to be most representative of these. These calculations were performed in the same manner as for gas model units, as described in Section 3.4.1 and demonstrated in Appendix C.

### **3.4.3 Exhaust Flowrate, Moisture and Percent Oxygen for Fuel Oil Model Units**

Residual oil average material analysis data (in percent by weight) were obtained for Sulfur, Hydrogen and Carbon.<sup>12</sup> These average percentages and the elements’ molecular weights were used to calculate the theoretical amount of Oxygen (mole/100 lb fuel) necessary for the combustion of residual oil. An average heating value in Btu/lb for residual oil was also obtained.<sup>12</sup> The ratio of Nitrogen to Oxygen in the atmosphere, the average heating value for residual oil, and the excess air percentage and exhaust temperature (discussed in Section 3.3) for residual liquid fossil fuel model units were used to calculate the exhaust flowrate (acfm), exhaust moisture content (%), and exhaust Oxygen content (% dry) for residual liquid fossil fuel model units. These parameters were calculated in the same manner for distillate liquid fossil fuel model units, but using the exhaust temperature determined for distillate oil.

### **3.4.4 Exhaust Flowrate, Moisture and Percent Oxygen for Coal Model Units**

Bituminous and sub-bituminous coal average material analysis data (in percent by weight) were obtained for Carbon, Hydrogen, Nitrogen, Sulfur, and Oxygen.<sup>12</sup> These average percentages and the elements’ molecular weights were used to calculate the theoretical amount of Oxygen (mole/100 lb fuel) necessary for the combustion of coal. An average heating value in Btu/lb for coal was also obtained.<sup>12</sup> The ratio of Nitrogen to Oxygen in the atmosphere, the average heating value for coal, and the excess air percentages and exhaust temperature (discussed in Section 3.3) for coal model units were used to calculate the exhaust flowrate (acfm), exhaust moisture content (%), and exhaust Oxygen content (% dry) for coal model units. These parameters were calculated separately for excess air percentages of 30% and 50%, to reflect the different capacity ranges for coal model units. In addition, these three parameters were calculated for model units with material combination “coal/wood/non-fossil liquid/non-fossil

solid” by averaging the parameters calculated for wood and coal. This calculation reflects that this material combination is best represented by 50% coal and 50% wood.

#### **3.4.5 Exhaust Flowrate, Moisture and Percent Oxygen for Non-fossil Model Units**

In order to develop typical parameters for the non-fossil model units, a representative fuel type had to be selected. The percent fuel input data for these units from the Survey component of the population database were reviewed to identify the main types of non-fossil materials included in these models. Many of the non-fossil materials were burned at very low percentages so that the main fuel inputs were comprised of mostly wood, biomass, or natural gas. The non-fossil materials burned at the highest input percentages, paper and tires, were chosen as being representative of the non-fossil model units. The ultimate fuel analyses for these materials were compared to the other materials, such as biomass, and it was determined that calculating model flowrates using paper or tires as a representative fuel would result in flowrates similar to those calculated for other model units. Therefore, average material analysis data (in percent by weight) for paper and tires were obtained from the ICCR Materials Analysis Database<sup>13</sup> for Carbon, Hydrogen, Nitrogen, Oxygen, and Sulfur. These average percentages and the elements’ molecular weights were used to calculate the theoretical amount of Oxygen (mole/100 lb fuel) necessary for the combustion of paper or tires. Average heating values in Btu/lb for paper and tires were also obtained from the Materials Analysis Database.<sup>13</sup> The ratio of Nitrogen to Oxygen in the atmosphere, the average heating value for these two non-fossil fuels, and the excess air percentages and exhaust temperature (discussed in Section 3.3) for non-fossil model units were used to calculate the exhaust flowrate (acfm), exhaust moisture content (%), and exhaust Oxygen content (% dry) for non-fossil model units. The calculated exhaust flowrate for tires was higher than that for paper, so, to be conservative, the exhaust flowrate, exhaust moisture content, and exhaust Oxygen content for tires were used to represent model units with the material combination “non-fossil liquid/non-fossil solid/gas”.

### **3.5 Final General Model Units**

Based on the review of available fuel, combustor design, and capacity data in MMBtu/hr in the population database, 81 general model units were developed. These model units are identified by model numbers 1 through 83 (models 51 and 71 were later determined to be

**Table 3-1. General Model Unit Parameters (Continued)**

unnecessary, but re-numbering models was not feasible at that point). Table 3-1 provides the parameters that define the general model units and the number of boilers and process heaters assigned to each one. Appendix D provides the additional parameters, such as exhaust flowrate, that were calculated for each of the general model units. Approximately 16% of boilers did not have adequate capacity data to be assigned to a model unit. Approximately 8% of process heaters did not have adequate fuel data and approximately 39% of process heaters did not have adequate capacity data to be assigned to a model unit. Section 5.0 discusses how these boilers and process heaters were incorporated into the model units.

**Table 3-1. General Model Unit Parameters**

Model Unit Parameters						Number Assigned to Model Unit	
Model No	Material Combination	Combustor Design	Capacity Range (MMBtu/hr)	Average Capacity (MMBtu/hr)	Annual Capacity Factor (%)	Boilers	Process Heaters
1	Coal	Other	0-10	4	60	56	0
2	Coal	Other	10-100	54	60	553	0
3	Coal	Other	100-250	166	60	298	0
4	Coal	Other	>250	565	60	116	0
5	Coal	Wall-fired/PC	0-10	2	60	6	0
6	Coal	Wall-fired/PC	10-100	57	60	46	0
7	Coal	Wall-fired/PC	100-250	186	60	98	0
8	Coal	Wall-fired/PC	>250	600	60	139	0
9	Coal/Wood/NFF Liquid/NFF Solid	All	0-10	6	57	7	0
10	Coal/Wood/NFF Liquid/NFF Solid	All	10-100	35	70	66	0
11	Coal/Wood/NFF Liquid/NFF Solid	All	100-250	173	76	17	0
12	Coal/Wood/NFF Liquid/NFF Solid	All	>250	565	83	76	0
13	Gas	All	0-10	3	62	16,993	4,374

**Table 3-1. General Model Unit Parameters (Continued)**

Model Unit Parameters						Number Assigned to Model Unit	
Model No	Material Combination	Combustor Design	Capacity Range (MMBtu/hr)	Average Capacity (MMBtu/hr)	Annual Capacity Factor (%)	Boilers	Process Heaters
14	Gas	All	10-100	33	63	8,961	2,119
15	Gas	All	100-250	164	64	994	508
16	Gas	All	>250	520	71	447	199
17	Gas/Wood/Other Biomass/Liquid FF	All	0-10	6	57	25	0
18	Gas/Wood/Other Biomass/Liquid FF	All	10-100	45	67	93	0
19	Gas/Wood/Other Biomass/Liquid FF	All	100-250	178	77	32	0
20	Gas/Wood/Other Biomass/Liquid FF	All	>250	394	80	43	0
21	Distillate Liquid FF	All	0-10	3	60	1,131	92
22	Distillate Liquid FF	All	10-100	29	60	462	55
23	Distillate Liquid FF	All	100-250	157	60	46	15
24	Distillate Liquid FF	All	>250	355	60	27	51
25	NFF Liquid/NFF Solid/Gas	All	0-10	6	62	6	1
26	NFF Liquid/NFF Solid/Gas	All	10-100	58	69	49	3
27	NFF Liquid/NFF Solid/Gas	All	100-250	161	64	32	4
28	NFF Liquid/NFF Solid/Gas	All	>250	562	75	21	0
29	Wood	Other	0-10	5	57	141	6
30	Wood	Other	10-100	30	64	336	26
31	Wood	Other	100-250	179	78	57	0

**Table 3-1. General Model Unit Parameters (Continued)**

Model Unit Parameters						Number Assigned to Model Unit	
Model No	Material Combination	Combustor Design	Capacity Range (MMBtu/hr)	Average Capacity (MMBtu/hr)	Annual Capacity Factor (%)	Boilers	Process Heaters
32	Wood	Other	>250	449	80	22	0
33	Wood	Wall-fired/PC	0-10	7	56	14	0
34	Wood	Wall-fired/PC	10-100	26	72	32	0
35	Wood	Wall-fired/PC	>250	677	70	2	0
36	Wood/Other Biomass/NFF Liquid/NFF Solid	All	0-10	7	68	10	0
37	Wood/Other Biomass/NFF Liquid/NFF Solid	All	10-100	44	64	30	0
38	Wood/Other Biomass/NFF Liquid/NFF Solid		100-250				
39	Wood/Other Biomass/NFF Liquid/NFF Solid		>250				
40	Residual Liquid FF	All	0-10	3	60	306	41
41	Residual Liquid FF	All	10-100	37	60	671	212
42	Residual Liquid FF	All	100-250	172	60	139	66
43	Residual Liquid FF	All	>250	547	60	75	17
44	Bagasse/Other	All	10-100	72	67	23	0
45	Bagasse/Other	All	100-250	158	82	22	0
46	Bagasse/Other	All	>250	419	80	37	0
47	Coal	Other	0-10	4	10	35	0
48	Coal	Other	10-100	54	10	47	0
49	Coal	Other	100-250	466	10	22	0
50	Coal	Other	>250	565	10	4	0

**Table 3-1. General Model Unit Parameters (Continued)**

Model Unit Parameters						Number Assigned to Model Unit	
Model No	Material Combination	Combustor Design	Capacity Range (MMBtu/hr)	Average Capacity (MMBtu/hr)	Annual Capacity Factor (%)	Boilers	Process Heaters
52	Coal	Wall-fired/PC	10-100	57	10	17	0
53	Coal	Wall-fired/PC	100-250	186	10	3	0
54	Coal	Wall-fired/PC	>250	600	10	5	0
55	Coal/Wood/NFF Liquid/NFF Solid	All	0-10	6	10	1	0
56	Coal/Wood/NFF Liquid/NFF Solid	All	10-100	35	10	2	0
57	Coal/Wood/NFF Liquid/NFF Solid	All	100-250	173	10	1	0
58	Gas	Other	0-10	3	10	1,444	233
59	Gas	Other	10-100	33	10	530	105
60	Gas	Other	100-250	164	10	68	6
61	Gas	Other	>250	520	10	22	10
62	Gas/Wood/Other Biomass/Liquid FF	All	0-10	6	10	2	0
63	Gas/Wood/Other Biomass/Liquid FF	All	10-100	45	10	3	0
64	Gas/Wood/Other Biomass/Liquid FF	All	100-250	178	10	2	0
65	Gas/Wood/Other Biomass/Liquid FF	All	>250	394	10	1	0
66	Distillate Liquid FF	All	0-10	3	10	247	8
67	Distillate Liquid FF	All	10-100	29	10	119	2
68	Distillate Liquid FF	All	100-250	157	10	22	1
69	Distillate Liquid FF	All	>250	355	10	5	1



**Table 3-1. General Model Unit Parameters (Continued)**

Model Unit Parameters						Number Assigned to Model Unit	
Model No	Material Combination	Combustor Design	Capacity Range (MMBtu/hr)	Average Capacity (MMBtu/hr)	Annual Capacity Factor (%)	Boilers	Process Heaters
70	NFF Liquid/NFF Solid/Gas	All	10-100	58	10	3	1
72	NFF Liquid/NFF Solid/Gas	All	>250	562	10	1	0
73	Wood	Other	0-10	5	10	13	0
74	Wood	Other	10-100	30	10	7	0
75	Wood	Other	100-250	179	10	1	0
76	Wood	Wall-fired/PC	0-10	7	10	2	0
77	Wood	Wall-fired/PC	10-100	26	10	1	0
78	Wood/Other Biomass/NFF Liquid/NFF Solid	All	0-10	7	10	1	0
79	Wood/Other Biomass/NFF Liquid/NFF Solid	All	10-100	44	10	3	0
80	Residual Liquid FF	All	0-10	3	10	117	6
81	Residual Liquid FF	All	10-100	37	10	183	12
82	Residual Liquid FF	All	100-250	172	10	40	0
83	Residual Liquid FF	All	>250	547	10	4	0
<b>Total</b>						<b>35,833</b>	<b>8,174</b>

## **4.0 MODEL UNIT CONTROL LEVEL DETERMINATION**

The 81 general model units were developed based on fuel, combustor design, and capacity data in the population database. These general model units were further divided to incorporate control devices that are included in the existing population. Developing model units with various levels of typical emission controls was necessary to calculate baseline emissions and cost and emissions impacts. This section discusses the development of the control level model units from the general model units.

### **4.1 Creation of Model Unit Control Levels**

Air pollution control device (APCD) data were available for approximately 18,800 of the 35,833 boilers that were assigned to the general model units. The existing control devices were grouped into ten basic control device categories: cyclone, electrostatic precipitator, packed scrubber, wet scrubber, duct sorbent injection, activated carbon injection, furnace sorbent injection, spray dryer, fabric filter, and no control. Controls such as low NO<sub>x</sub> burners, over-fire air, and fuel-low sulfur content were assumed to have no effect on HAP emissions and were included in the “no control” category. Control device grouping and efficiencies are discussed in another memorandum.<sup>14,15</sup> The APCD data were reviewed to determine control device combinations that would accurately represent each model unit’s control level. The following 17 model unit unique control combinations were developed, based on information in the population database and engineering judgement:

- Cyclone;
- Cyclone/Packed Scrubber;
- Electrostatic Precipitator;
- Electrostatic Precipitator/Activated Carbon Adsorption;
- Electrostatic Precipitator/Duct Sorbent Injection;
- Electrostatic Precipitator/Furnace Sorbent Injection;
- Electrostatic Precipitator/Spray Dryer;
- Electrostatic Precipitator/Packed Scrubber;
- Electrostatic Precipitator/Wet Scrubber;

- Fabric Filter;
- Fabric Filter/Duct Sorbent Injection;
- Fabric Filter/Furnace Sorbent Injection;
- Fabric Filter/Spray Dryer;
- Fabric Filter/Wet Scrubber;
- No Control;
- Packed Scrubber; and
- Wet Scrubber.

#### **4.2 Assigning Model Unit Control Levels to Boilers and Process Heaters**

Air pollution control device data are contained in a “Control Device Code” field in both the Inventory and Survey components of the population database. The control device codes correspond to control device descriptions, provided in a reference table in the database.

Combustion units with APCD data may have one or more control device codes associated with them. For example, a boiler with the codes 016 and 041 has a fabric filter and dry limestone injection as control devices. Many combustion units in the Inventory component of the population database have the control device code 000, which indicates that a unit does not have any type of control device.

Because there was such a large number of combustion units in the Inventory component of the population database that did not have control device information, making an assumption that all these units were uncontrolled would have skewed the analysis. In many cases, almost all units from an entire state would have missing control device information (as provided in the original data sources). For the purposes of developing model units, it was assumed that the units without control information would have similar controls to the units that had control information available. Therefore, the units from the Inventory component of the population database without control information were distributed into the control level model units, as described in Section 5.0. However, combustion units without a control device code in the Survey component of the population database were assumed to be uncontrolled and were assigned the model unit control level of “No Control”. This assumption was made because the Survey database is a compilation of responses to an ICR questionnaire which did not include a check box or a code for a facility to

indicate that its combustion unit does not have a control device. Therefore, a blank response is assumed to indicate that the unit does not have a control device.

### **4.3 Final Control Level Model Units**

Based on the review of available APCD data in the population database, 283 control level model units were developed from the 81 general model units. These model units are identified by the general model numbers 1 through 83 (minus 51 and 71) followed by letters a, b, c, and so on, depending on the number of control levels created for a given general model unit. For example, model unit 30, which is defined by Wood, Fluidized Bed/Stoker/Dutch Oven/Other, 10-100 MMBtu/hr, was subdivided into 30a, 30b, 30c, 30d, and 30e for the corresponding control device levels “No Control”, “Cyclone”, “Electrostatic Precipitator”, “Fabric Filter”, and “Wet Scrubber”, respectively. Appendix E provides the parameters that define the specific control level model units and the number of boilers and process heaters assigned to each one. In addition to the percentages of boilers and process heaters that do not have adequate capacity or fuel data to be assigned to general model units, approximately 39% of boilers and approximately 34% of process heaters do not have adequate control device data to be assigned to a control level model unit. Sections 5.2 and 5.5 discuss how these boilers and process heaters were incorporated into the model units, respectively.

## **5.0 DISTRIBUTION OF COMBUSTION UNITS WITH MISSING DATA**

### **5.1 Distribution of Boilers Without Capacity Data in MMBtu/hr**

There were approximately 7,100 boilers (that have fuel data) in the population database either with capacity data in units of measure other than MMBtu/hr that could not be converted into MMBtu/hr, with capacity data that were determined to be erroneous (as discussed in Section 2.3.3), or without capacity data at all. These boilers could not be assigned a specific model unit capacity range. In order to incorporate these boilers into the impacts analysis, they were distributed among the four model unit capacity ranges, based on their material combination and combustor design type, and then distributed into the control level model units.

First, the percentages of boilers which were assigned to each model unit capacity range for each combination of material and combustor design type were determined. For example, for non-limited use boilers which have capacity data in MMBtu/hr and were assigned the “Coal” material combination and “Wall-fired/Pulverized Coal” combustor design: 2% are 0-10 MMBtu/hr; 16% are 10-100 MMBtu/hr; 34% are 100-250 MMBtu/hr; and 48% are >250 MMBtu/hr. Then, the percentages of boilers with available control device data which were assigned to each model unit control level were determined. For example, for non-limited use boilers (with known fuel, capacity, and control device data) assigned to “Coal”, “Wall-fired/Pulverized Coal”, and “0-10 MMBtu/hr”, 80% have the control level of “No Control”. The number of boilers without capacity data multiplied by these two percentages determined the number of boilers distributed into each control level model unit. For example, out of the 6,330 non-limited use boilers without capacity data, the 324 that are “Coal” and “Wall-fired/Pulverized Coal”, multiplied by 2% and 80%, results in 5 boilers without capacity data being distributed into the control level model unit for non-limited use units defined by “Coal”, “Wall-fired/Pulverized Coal”, “0-10 MMBtu/hr”, and “No Control”. The percentages of the boiler population which were assigned model unit parameters were used to distribute those boilers without capacity data in MMBtu/hr into the appropriate control level model units for the purpose of totaling the number of boilers in each model unit for the impacts analysis. It was assumed that the boiler population in which data were unknown would have the same model unit parameter distribution as the known population.

## **5.2 Distribution of Boilers Without Control Device Data**

Control device data are not available for approximately 16,700 boilers (although fuel and capacity data are available) in the population database. These boilers could not be assigned a specific model unit control level, but were distributed into control level model units based on percentages of boilers with fuel, capacity in MMBtu/hr, and control device data. This distribution was done in a similar manner as for boilers without capacity data in MMBtu/hr, as described in Section 5.1. However, these 16,700 boilers have all the necessary data to be assigned to a control level model unit except control device data. Therefore, these boilers were distributed into control level model units based only on the percentages of boilers with known data that were assigned to each control level model unit (only one step was required). For

example, for non-limited use boilers assigned the model parameters “Distillate Liquid FF” and “10-100 MMBtu/hr” (that have control device data), 96.5% have the control level of “No Control”. Out of the 16,700 boilers without control device data, 202 are non-limited use and are assigned to “Distillate Liquid FF” and “10-100 MMBtu/hr”. Therefore, the number of boilers without control device data distributed into the control level model unit for non-limited use units defined by “Distillate Liquid FF”, “10-100 MMBtu/hr”, and “No Control” would be 202 multiplied by 96.5%, or 195 boilers.

### **5.3 Distribution of Process Heaters Without Fuel Data**

The 1,140 process heaters in the population database without fuel data constitute approximately 8% of the total process heater population. Because the process heaters without fuel data constitute a significant percentage of the overall process heater population, they needed to be incorporated into model units. Therefore, the 1,140 process heaters were distributed into the final control level model units. One difference in the distribution methodology for process heaters with unknown data as compared to that for boilers with unknown data was that it was assumed that process heaters with unknown data were small heaters, because there are fewer process heaters in the higher capacity ranges and these larger heaters would be more likely to have complete information in the database. Therefore, the heaters with unknown data were distributed into control level model units with the capacity ranges of 0-10 and 10-100 MMBtu/hr only.

First, the percentages of process heaters with available fuel data assigned to each model unit material combination were determined. For example, the percentages of process heaters (with known fuel data) assigned to the material combinations of “Gas” and “Residual Liquid Fossil Fuel” are 92.5% and 5%, respectively. The percentages of process heaters with known capacity data assigned to the model unit capacity ranges of 0-10 and 10-100 MMBtu/hr were then determined. For example, for process heaters (with known fuel and capacity data) assigned to the material combination of “Gas” and assigned to either “0-10 MMBtu/hr” or “10-100 MMBtu/hr”, 67.5% have the capacity range of “0-10 MMBtu/hr” and 32.5% have the capacity range of “10-100 MMBtu/hr”. These two percentages were calculated based on the above assumption that process heaters with unknown data are smaller heaters. Finally, the percentages of process heaters with available control device data which were assigned to each model unit

control level were determined. For example, for process heaters (with known fuel, capacity, and control device data) assigned to “Gas” and “0-10 MMBtu/hr”, 96% have the control level of “No Control”. The number of process heaters without fuel data multiplied by these three percentages determined the number of process heaters distributed into each control level model unit. For example, 1,140 multiplied by 92.5%, 67.5%, and 96% resulted in 683 process heaters without fuel data being distributed into the control level model unit for “Gas”, “0-10 MMBtu/hr”, and “No Control”. The percentages of the process heater population which were assigned model unit parameters were used to distribute those process heaters without fuel data into the appropriate control level model units for the purpose of totaling the number of process heaters in each model unit for the impacts analysis.

#### **5.4 Distribution of Process Heaters Without Capacity Data in MMBtu/hr**

Heat input capacities in MMBtu/hr or SCC capacity range data were not available for 5,934 of the 14,108 process heaters with fuel data in the population database. These process heaters were distributed into the appropriate control level model units based on percentages of process heaters with known data. This distribution was done in a similar manner as for those process heaters without fuel data, as described in Section 5.3. However, these 5,934 process heaters have fuel data, and therefore, only the percentages of heaters in each model unit capacity range and control level are needed for the distribution. For example, for process heaters with fuel and capacity data that are assigned to “Gas” and assigned to either “0-10 MMBtu/hr” or “10-100 MMBtu/hr”, 67.5% have the capacity range of “0-10 MMBtu/hr”. For process heaters with fuel, capacity, and control device data that are assigned to “Gas” and “0-10 MMBtu/hr”, 96% have the control level of “No Control”. Out of the 5,934 process heaters without capacity data in MMBtu/hr, 5,495 are gas heaters. Therefore, the number of process heaters without capacity data in MMBtu/hr that were distributed into the control level model unit defined by “Gas”, “0-10 MMBtu/hr”, and “No Control”, would be 5,495 multiplied by 67.5% and 96%, or 3,561 process heaters.

#### **5.5 Distribution of Process Heaters Without Control Device Data**

Control device data are not available for 5,183 process heaters (that have fuel and capacity data) in the population database. These process heaters could not be assigned a specific

model unit control level, but rather, were distributed into control level model units based on percentages of process heaters with fuel, capacity in MMBtu/hr, and control device data. This distribution was done in a similar manner as for those process heaters without capacity data in MMBtu/hr, as described in Section 5.4. However, these 5,183 process heaters have all the necessary data to be assigned to a control level model unit except control device data. Therefore, these process heaters were distributed into control level model units based only on the percentages of process heaters with known data that were assigned to each control level model unit (only one step was required). For example, for process heaters assigned the model parameters of “Distillate Liquid Fossil Fuel” and “0-10 MMBtu/hr”, 90% have the control level of “No Control”. Out of the 5,183 process heaters without control device data, 59 are assigned the model parameters of “Distillate Liquid Fossil Fuel” and “0-10 MMBtu/hr”. Therefore, the number of process heaters without control device data distributed into the control level model unit defined by “Distillate Liquid Fossil Fuel”, “0-10 MMBtu/hr”, and “No Control” would be 59 multiplied by 90%, or 53 process heaters.

## **5.6 Summary of Distribution of Boilers and Process Heaters and Final Model Units**

Overall, 55% of boilers (that have fuel data available) and 80% of process heaters in the population database could not be assigned to a control level model unit. Because the units with missing information span all locations and types of units, it is assumed that the parameters for these units would be similar to the parameters represented by the units with all information available. Therefore, these boilers and process heaters were distributed into the control level model units based on the distribution of boilers and process heaters with known fuel data, capacity data in MMBtu/hr, and control device data. Appendix F-1 provides the number of boilers and process heaters that were actually assigned to each control level model unit, the number of units that were distributed into each control level model unit, and the total number of units associated with each control level model unit. In addition, Appendix F-2 provides these numbers of boilers and process heaters summed per general model unit.



## 6.0 REFERENCES

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## Appendix A

### ICR Questionnaire Boiler Design Options

#### 5. Description

##### a. Boilers (indicate all that apply)

- ☐ Field-erected
- ☐ Package
- ☐ Water tube
- ☐ Fire tube
- ☐ Dutch Oven
- ☐ Coil Tube
- ☒ Cell Type
- ☐ Pulverized Coal
- ☐ Moving Grate Stoker
- ☐ Spreader Stoker
- ☐ Vibratory Stoker
- ☒ Circulating Fluidized Bed
- ☐ Bubbling Fluidized Bed
- ☐ Mass Feed
- ☐ Pneumatically fed
- ☐ Under Feed
- ☐ Semi-suspension
- ☐ Full suspension
- ☐ Wet Bottom
- ☐ Dry Bottom
- ☐ Wall-Fired
- ☐ Tangentially-Fired
- ☐ Cyclone-Fired
- ☐ Fixed Grate
- ☐ Natural Draft
- ☐ Forced Draft
- ☐ Induced Draft
- ☐ Balanced Draft
- ☐ Air Preheat
- ☐ Coal converted to liquid or gas
- ☐ Other: \_\_\_\_\_

## Appendix B

### Equations for Capacity Conversions

1. To convert 1000 lb of steam/hr to MMBtu/hr (Steam, pages 2-2; 2-3)<sup>a</sup>:

$$\frac{1150 \text{ Btu}}{\text{lb of steam}} \left| \frac{\text{MMBtu}}{10^6 \text{ Btu}} \right| \frac{1000 \text{ lb of steam}}{1000 \text{ lb of steam}} = \frac{1.15 \text{ MMBtu}}{1000 \text{ lb of steam}}$$

2. To convert lb of steam/hr to MMBtu/hr (Steam, pages 2-2; 2-3)<sup>a</sup>:

$$\frac{1150 \text{ Btu}}{\text{lb of steam}} \left| \frac{\text{MMBtu}}{10^6 \text{ Btu}} \right| = \frac{0.00115 \text{ MMBtu}}{\text{lb of steam}}$$

3. To convert gallon/minute of #2 fuel oil to MMBtu/hr (Steam, page 8-15)<sup>a</sup>:

$$\frac{19,460 \text{ Btu}}{\text{lb}} \left| \frac{7.13 \text{ lb}}{\text{gal}} \right| \left| \frac{\text{MMBtu}}{10^6 \text{ Btu}} \right| \frac{60 \text{ min}}{\text{hr}} = \frac{8.32 \text{ MMBtu/hr}}{\text{gal}}$$

4. To convert ton/day of wood to MMBtu/hr (Steam, page 8-18)<sup>a</sup>:

$$\frac{8,623 \text{ Btu}}{\text{lb}} \left| \frac{\text{MMBtu}}{10^6 \text{ Btu}} \right| \frac{2000 \text{ lb}}{\text{ton}} \left| \frac{\text{day}}{24 \text{ hr}} \right| = \frac{0.719 \text{ MMBtu/hr}}{\text{lb}}$$

5. To convert lb/hr of wood to MMBtu/hr (Steam, page 8-18)<sup>a</sup>:

$$\frac{8,623 \text{ Btu}}{\text{lb}} \left| \frac{\text{MMBtu}}{10^6 \text{ Btu}} \right| = \frac{0.0086 \text{ MMBtu}}{\text{lb}}$$

6. To convert ton/yr of wood to MMBtu/hr (Steam, page 8-18)<sup>a</sup>:

$$\frac{8,623 \text{ Btu}}{\text{lb}} \left| \frac{\text{MMBtu}}{10^6 \text{ Btu}} \right| \frac{2000 \text{ lb}}{\text{ton}} \left| \frac{\text{yr}}{8,760 \text{ hr}} \right| = \frac{0.002 \text{ MMBtu/hr}}{\text{lb}}$$

7. To convert ton/hr of wood to MMBtu/hr (Steam, page 8-18)<sup>a</sup>:

$$\frac{8,623 \text{ Btu}}{\text{lb}} \left| \frac{\text{MMBtu}}{10^6 \text{ Btu}} \right| \frac{2000 \text{ lb}}{\text{ton}} = \frac{17.25 \text{ MMBtu}}{\text{lb}}$$

8. To convert horsepower to MMBtu/hr (Steam, pages T-3, T-17)<sup>a</sup>:

$$\frac{42.44 \text{ Btu} \mid 60 \text{ min} \mid \text{MMBtu}}{\mid \text{min} \mid \text{hr} \mid 10^6 \text{ Btu} \mid 0.85} = \frac{0.003 \text{ MMBtu/hr}}{\text{hp}}$$

9. To convert kilowatts to MMBtu/hr (Steam, pages T-3, T-17)<sup>a</sup>:

$$\frac{56.91 \text{ Btu} \mid 60 \text{ min} \mid \text{MMBtu}}{\mid \text{min} \mid \text{hr} \mid 10^6 \text{ Btu} \mid 0.35} = \frac{0.0098 \text{ MMBtu/hr}}{\text{kW}}$$

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## Appendix C

### Example Calculation of Exhaust Flowrate, Moisture and Percent Oxygen for Gas Model Unit

#### Material Analysis Average Values and Average Heating Value for Natural Gas from *Steam*<sup>10</sup>

Hydrogen (H<sub>2</sub>): 22.7 % by weight  
 Carbon (C): 70.6 % by weight  
 Nitrogen (N<sub>2</sub>): 5.7 % by weight  
 Oxygen (O<sub>2</sub>): 1.0 % by weight

Heating Value: 22,027 Btu/lb

#### Ratio of Nitrogen to Oxygen in the Atmosphere

Ratio: 3.77 moles N<sub>2</sub> / 1 mole O<sub>2</sub>

#### Excess Air and Exhaust Temperature for Gas Model Units from BIDs<sup>8,9</sup>

Excess Air: 15 %  
 Exhaust Temperature: 350 deg F

#### Calculate Theoretical Oxygen Requirement in Combustion Air

Element	% by weight	Molecular Weight (MW)	Mole/100 lb of fuel = (%/MW)	Product	Required moles of O <sub>2</sub> /100 lb fuel
C	70.6	12	5.9	CO <sub>2</sub>	5.9
H <sub>2</sub>	22.7	2	11.4	H <sub>2</sub> O	5.7
O <sub>2</sub>	1.0	32	0.03	---	-0.03
N <sub>2</sub>	5.7	28	0.2	---	---
<b>Total</b>	100	---	---	---	11.6

#### Calculate Heat Content of Natural Gas per 100 Pounds of Fuel

$$\frac{22,027 \text{ Btu}}{\text{lb fuel}} \times \frac{100}{100 \text{ lb fuel}} \times \frac{\text{MMBtu}}{10^6 \text{ Btu}} = \frac{2.2 \text{ MMBtu}}{100 \text{ lb fuel}}$$

#### Solve for Required Moles of O<sub>2</sub>/100 lb fuel at 15% Excess Air

$$15 = 100 \times \frac{(\text{O}_2 - 11.6)}{(11.6)} ; \text{O}_2 = 13.3 \text{ moles O}_2/100 \text{ lb fuel}$$

#### Calculate Moles of N<sub>2</sub>/100 lb fuel in Combustion Air

$$\text{N}_2 = \frac{13.3 \text{ moles O}_2}{100 \text{ lb fuel}} \times \frac{3.77 \text{ moles N}_2}{1.0 \text{ moles O}_2} = 50.1 \text{ moles N}_2/100 \text{ lb fuel}$$

### Determine Exhaust Totals

Element/Compound	Basis	Exhaust (moles/100 lb fuel)
CO <sub>2</sub>	5.9 C	5.9
H <sub>2</sub> O	11.4 H <sub>2</sub>	11.4
O <sub>2</sub>	13.3 - 11.6	1.7
N <sub>2</sub>	0.2 + 50.1	50.3
Total	---	69.3

### Calculate Moisture Content in the Exhaust

$$\text{Exhaust Moisture (\%)} = (11.4 / 69.3) \times 100\% = 16.5\%$$

### Calculate Oxygen Content in the Exhaust

$$\text{Exhaust Oxygen (\%, dry)} = \frac{1.7}{69.3 - 11.4} \times 100\% = 2.9\%$$

### Calculate Exhaust Volume using Equation:

Pressure X Volume = Moles X Constant X Temperature

$$\text{Exhaust Volume} = \frac{69.3 \text{ lb-moles}}{100 \text{ lb fuel}} \times \frac{10.73 \text{ psia-ft}^3}{\text{lb-mole-deg R}} \times \frac{1}{14.7 \text{ psia}} \times (350 \text{ deg F} + 460 \frac{\text{deg R}}{\text{deg F}})$$

$$\text{Exhaust Volume} = 409.73 \text{ acf/lb fuel @ 15\% excess air}$$

### Convert Exhaust Volume by Multiplying by the Heat Content of Natural Gas

$$\text{Exhaust Volume} = \frac{409.73 \text{ acf}}{\text{lb fuel}} \times \frac{100 \text{ lb fuel}}{2.2 \text{ MMBtu}} = 18,624 \text{ acf/MMBtu @ 15\% excess air}$$

### Calculate Exhaust Flowrate from Exhaust Volume using Average Capacity (MMBtu/hr) for Model Unit

Model unit with capacity range 0-10 MMBtu/hr has average capacity of 2.77 MMBtu/hr.

$$\text{Exhaust Flowrate} = \frac{18,624 \text{ acf}}{\text{MMBtu}} \times \frac{2.77 \text{ MMBtu}}{\text{hour}} \times \frac{1 \text{ hr}}{60 \text{ minutes}} = 859.8 \text{ acfm}$$

## **Appendix D**

### **Additional Model Unit Parameters**

(See Excel spreadsheet “ModelappD-F.xls”)



# Appendix D. Additional Model Unit Parameters

Model Unit Parameters										
Model No	Limited Use Model No	Material	Combustor Type	Capacity Range (MMBtu/hr)	Average Capacity (MMBtu/hr)	Excess Air (%)	Exhaust Temp. (F)	Exhaust Flow (acfm)	O2 in Exhaust (% dry)	Exhaust Moisture (%)
1	47	Coal	Other	0-10	4	50	400	2,143	7.1	4.8
2	48	Coal	Other	10-100	54	50	400	26,346	7.1	4.8
3	49	Coal	Other	100-250	167	50	400	81,219	7.1	4.8
4	50	Coal	Other	>250	565	30	400	239,166	5.0	5.5
5		Coal	Wall-fired/PC	0-10	2	50	400	1,193	7.1	4.8
6	52	Coal	Wall-fired/PC	10-100	57	50	400	27,953	7.1	4.8
7	53	Coal	Wall-fired/PC	100-250	186	50	400	90,618	7.1	4.8
8	54	Coal	Wall-fired/PC	>250	600	30	400	253,984	5.0	5.5
9	55	Coal/Wood/NFF Liquid/NFF Solid	All	0-10	6	50	400	2,652	7.1	10.8
10	56	Coal/Wood/NFF Liquid/NFF Solid	All	10-100	35	50	400	16,524	7.1	10.8
11	57	Coal/Wood/NFF Liquid/NFF Solid	All	100-250	173	50	400	82,361	7.1	10.8
12		Coal/Wood/NFF Liquid/NFF Solid	All	>250	565	50	400	269,705	7.1	10.8
13	58	Gas	Other	0-10	3	15	350	860	2.9	16.5
14	59	Gas	Other	10-100	33	15	350	10,327	2.9	16.5
15	60	Gas	Other	100-250	164	15	350	50,974	2.9	16.5
16	61	Gas	Other	>250	520	15	350	161,445	2.9	16.5
17	62	Gas/Wood/Other Biomass/Liquid FF	All	0-10	6	50	400	2,841	7.0	17.0
18	63	Gas/Wood/Other Biomass/Liquid FF	All	10-100	45	50	400	20,908	7.0	17.0
19	64	Gas/Wood/Other Biomass/Liquid FF	All	100-250	178	50	400	83,040	7.0	17.0
20	65	Gas/Wood/Other Biomass/Liquid FF	All	>250	394	50	400	184,101	7.0	17.0
21		Distillate Liquid FF	All	0-10	3	15	400	903	2.8	9.5
22	67	Distillate Liquid FF	All	10-100	29	15	400	9,854	2.8	9.5
23	68	Distillate Liquid FF	All	100-250	157	15	400	52,424	2.8	9.5
24	69	Distillate Liquid FF	All	>250	356	15	400	118,951	2.8	9.5
25		NFF Liquid/NFF Solid/Gas	All	0-10	6	50	400	2,759	7.2	5.3
26	70	NFF Liquid/NFF Solid/Gas	All	10-100	58	50	400	26,063	7.2	5.3
27		NFF Liquid/NFF Solid/Gas	All	100-250	161	50	400	72,205	7.2	5.3
28	72	NFF Liquid/NFF Solid/Gas	All	>250	562	50	400	251,654	7.2	5.3
29	73	Wood	Other	0-10	5	50	400	2,536	7.0	17.0
30	74	Wood	Other	10-100	30	50	400	13,998	7.0	17.0
31	75	Wood	Other	100-250	179	50	400	83,891	7.0	17.0
32		Wood	Other	>250	449	50	400	209,961	7.0	17.0
33	76	Wood	Wall-fired/PC	0-10	7	50	400	3,238	7.0	17.0
34	77	Wood	Wall-fired/PC	10-100	26	50	400	12,112	7.0	17.0
35		Wood	Wall-fired/PC	>250	677	50	400	316,196	7.0	17.0
36	78	Wood/Other Biomass/NFF Liquid/NFF Solid	All	0-10	7	50	400	3,334	7.0	17.0
37	79	Wood/Other Biomass/NFF Liquid/NFF Solid	All	10-100	44	50	400	20,665	7.0	17.0
38		Wood/Other Biomass/NFF Liquid/NFF Solid	All	100-250	173	50	400	80,822	7.0	17.0
39		Wood/Other Biomass/NFF Liquid/NFF Solid	All	>250	513	50	400	239,844	7.0	17.0
40	80	Residual Liquid FF	All	0-10	3	15	400	1,094	2.8	9.5
41	81	Residual Liquid FF	All	10-100	37	15	400	12,329	2.8	9.5
42	82	Residual Liquid FF	All	100-250	172	15	400	57,650	2.8	9.5
43	83	Residual Liquid FF	All	>250	547	15	400	183,162	2.8	9.5
44		Bagasse/Other	All	10-100	72	50	400	20,908	7.0	17.0
45		Bagasse/Other	All	100-250	158	50	400	83,891	7.0	17.0
46		Bagasse/Other	All	>250	419	50	400	316,196	7.0	17.0

Note: Combustor Type "All" refers to Fluidized Bed/Stoker/DOWall-fired/PC/Other

## **Appendix E**

### **Control Level Model Unit Parameters Table**

(See Excel spreadsheet “ModelappD-F.xls”)

## Appendix E. Control Level Model Unit Parameters

Model Unit Parameters						Number Assigned	
Model No	Material Combination	Combustor Design	Capacity Range (MMBtu/hr)	Average Capacity (MMBtu/hr)	Control Level	Boilers	Process Heaters
1a	Coal	Other	0-10	4	No Control	18	0
1b	Coal	Other	0-10	4	Cyclone	12	0
1c	Coal	Other	0-10	4	FF	1	0
2a	Coal	Other	10-100	54	No Control	70	0
2b	Coal	Other	10-100	54	Cyclone	198	0
2c	Coal	Other	10-100	54	ESP	56	0
2d	Coal	Other	10-100	54	FF	82	0
2e	Coal	Other	10-100	54	FF/DSI	2	0
2f	Coal	Other	10-100	54	FF/SD	2	0
2g	Coal	Other	10-100	54	Wet Scrubber	7	0
3a	Coal	Other	100-250	166	No Control	22	0
3b	Coal	Other	100-250	166	Cyclone	79	0
3c	Coal	Other	100-250	166	ESP	53	0
3d	Coal	Other	100-250	166	ESP/Wet Scrubber	1	0
3e	Coal	Other	100-250	166	FF	76	0
3f	Coal	Other	100-250	166	FF/DSI	2	0
3g	Coal	Other	100-250	166	FF/Wet Scrubber	2	0
3h	Coal	Other	100-250	166	Wet Scrubber	7	0
4a	Coal	Other	>250	565	No Control	12	0
4b	Coal	Other	>250	565	Cyclone	7	0
4c	Coal	Other	>250	565	ESP	20	0
4d	Coal	Other	>250	565	ESP/DSI	1	0
4e	Coal	Other	>250	565	ESP/Wet Scrubber	2	0
4f	Coal	Other	>250	565	FF	28	0
4g	Coal	Other	>250	565	FF/DSI	20	0
4h	Coal	Other	>250	565	FF/FSI	5	0
4i	Coal	Other	>250	565	FF/SD	3	0
4j	Coal	Other	>250	565	Wet Scrubber	4	0
5a	Coal	Wall-fired/PC	0-10	2	No Control	4	0
5b	Coal	Wall-fired/PC	0-10	2	Cyclone	1	0
6a	Coal	Wall-fired/PC	10-100	57	No Control	6	0
6b	Coal	Wall-fired/PC	10-100	57	Cyclone	2	0
6c	Coal	Wall-fired/PC	10-100	57	ESP	16	0
6d	Coal	Wall-fired/PC	10-100	57	FF	12	0
6e	Coal	Wall-fired/PC	10-100	57	FF/DSI	1	0
6f	Coal	Wall-fired/PC	10-100	57	Wet Scrubber	5	0
7a	Coal	Wall-fired/PC	100-250	186	No Control	5	0
7b	Coal	Wall-fired/PC	100-250	186	Cyclone	2	0
7c	Coal	Wall-fired/PC	100-250	186	Cyclone/Packed Scrubber	2	0
7d	Coal	Wall-fired/PC	100-250	186	ESP	40	0
7e	Coal	Wall-fired/PC	100-250	186	FF	34	0
7f	Coal	Wall-fired/PC	100-250	186	FF/SD	1	0
7g	Coal	Wall-fired/PC	100-250	186	FF/Wet Scrubber	1	0
7h	Coal	Wall-fired/PC	100-250	186	Wet Scrubber	6	0
8a	Coal	Wall-fired/PC	>250	600	No Control	7	0
8c	Coal	Wall-fired/PC	>250	600	ESP	82	0
8d	Coal	Wall-fired/PC	>250	600	ESP/SD	2	0
8e	Coal	Wall-fired/PC	>250	600	ESP/Packed Scrubber	3	0
8f	Coal	Wall-fired/PC	>250	600	ESP/Wet Scrubber	5	0
8g	Coal	Wall-fired/PC	>250	600	FF	15	0
8h	Coal	Wall-fired/PC	>250	600	FF/DSI	5	0
8i	Coal	Wall-fired/PC	>250	600	FF/SD	1	0
8j	Coal	Wall-fired/PC	>250	600	FF/Wet Scrubber	1	0
8k	Coal	Wall-fired/PC	>250	600	Wet Scrubber	1	0
9a	Coal/Wood/NFF Liquid/NFF Solid	All	0-10	6	No Control	2	0
9b	Coal/Wood/NFF Liquid/NFF Solid	All	0-10	6	Cyclone	4	0
10a	Coal/Wood/NFF Liquid/NFF Solid	All	10-100	35	No Control	8	0
10b	Coal/Wood/NFF Liquid/NFF Solid	All	10-100	35	Cyclone	53	0
10c	Coal/Wood/NFF Liquid/NFF Solid	All	10-100	35	ESP	5	0
11a	Coal/Wood/NFF Liquid/NFF Solid	All	100-250	173	Cyclone	3	0
11b	Coal/Wood/NFF Liquid/NFF Solid	All	100-250	173	ESP	10	0
11c	Coal/Wood/NFF Liquid/NFF Solid	All	100-250	173	Wet Scrubber	2	0
11d	Coal/Wood/NFF Liquid/NFF Solid	All	100-250	173	FF	2	0
12a	Coal/Wood/NFF Liquid/NFF Solid	All	>250	565	Cyclone	1	0
12b	Coal/Wood/NFF Liquid/NFF Solid	All	>250	565	Cyclone/Packed Scrubber	4	0
12c	Coal/Wood/NFF Liquid/NFF Solid	All	>250	565	ESP	45	0
12d	Coal/Wood/NFF Liquid/NFF Solid	All	>250	565	ESP/FSI	1	0

# Appendix E. Control Level Model Unit Parameters

Model Unit Parameters						Number Assigned	
Model No	Material Combination	Combustor Design	Capacity Range (MMBtu/hr)	Average Capacity (MMBtu/hr)	Control Level	Boilers	Process Heaters
12e	Coal/Wood/NFF Liquid/NFF Solid	All	>250	565	ESP/SD	4	0
12f	Coal/Wood/NFF Liquid/NFF Solid	All	>250	565	FF	5	0
12g	Coal/Wood/NFF Liquid/NFF Solid	All	>250	565	FF/FSI	7	0
12h	Coal/Wood/NFF Liquid/NFF Solid	All	>250	565	FF/Wet Scrubber	2	0
12i	Coal/Wood/NFF Liquid/NFF Solid	All	>250	565	Wet Scrubber	6	0
13a	Gas	All	0-10	3	No Control	8,016	1,425
13b	Gas	All	0-10	3	Cyclone	39	5
13c	Gas	All	0-10	3	ESP	4	19
13d	Gas	All	0-10	3	FF	79	11
13e	Gas	All	0-10	3	FF/DSI	2	0
13f	Gas	All	0-10	3	FF/Wet Scrubber	4	0
13g	Gas	All	0-10	3	Packed Scrubber	4	0
13h	Gas	All	0-10	3	Wet Scrubber	22	22
14a	Gas	All	10-100	33	No Control	4,665	691
14b	Gas	All	10-100	33	Cyclone	57	1
14c	Gas	All	10-100	33	ESP	11	0
14d	Gas	All	10-100	33	FF	33	5
14e	Gas	All	10-100	33	FF/Wet Scrubber	6	0
14f	Gas	All	10-100	33	Wet Scrubber	40	25
15a	Gas	All	100-250	164	No Control	487	168
15b	Gas	All	100-250	164	Cyclone	10	0
15c	Gas	All	100-250	164	ESP	8	0
15d	Gas	All	100-250	164	ESP/Wet Scrubber	1	1
15e	Gas	All	100-250	164	FF	4	0
15f	Gas	All	100-250	164	Wet Scrubber	9	11
16a	Gas	All	>250	520	No Control	224	83
16b	Gas	All	>250	520	Cyclone	3	6
16c	Gas	All	>250	520	ESP	6	0
16d	Gas	All	>250	520	Wet Scrubber	4	5
17a	Gas/Wood/Other Biomass/Liquid FF	All	0-10	6	No Control	9	0
17b	Gas/Wood/Other Biomass/Liquid FF	All	0-10	6	Cyclone	10	0
17c	Gas/Wood/Other Biomass/Liquid FF	All	0-10	6	FF	2	0
17d	Gas/Wood/Other Biomass/Liquid FF	All	0-10	6	Wet Scrubber	2	0
18a	Gas/Wood/Other Biomass/Liquid FF	All	10-100	45	No Control	11	0
18b	Gas/Wood/Other Biomass/Liquid FF	All	10-100	45	Cyclone	60	0
18c	Gas/Wood/Other Biomass/Liquid FF	All	10-100	45	ESP	12	0
18d	Gas/Wood/Other Biomass/Liquid FF	All	10-100	45	ESP/Wet Scrubber	1	0
18e	Gas/Wood/Other Biomass/Liquid FF	All	10-100	45	FF	1	0
18f	Gas/Wood/Other Biomass/Liquid FF	All	10-100	45	FF/Wet Scrubber	1	0
18g	Gas/Wood/Other Biomass/Liquid FF	All	10-100	45	Wet Scrubber	3	0
19b	Gas/Wood/Other Biomass/Liquid FF	All	100-250	178	Cyclone	4	0
19c	Gas/Wood/Other Biomass/Liquid FF	All	100-250	178	Cyclone/Packed Scrubber	1	0
19d	Gas/Wood/Other Biomass/Liquid FF	All	100-250	178	ESP	11	0
19e	Gas/Wood/Other Biomass/Liquid FF	All	100-250	178	ESP/Wet Scrubber	1	0
19f	Gas/Wood/Other Biomass/Liquid FF	All	100-250	178	Wet Scrubber	13	0
20a	Gas/Wood/Other Biomass/Liquid FF	All	>250	394	Cyclone	4	0
20b	Gas/Wood/Other Biomass/Liquid FF	All	>250	394	ESP	10	0
20c	Gas/Wood/Other Biomass/Liquid FF	All	>250	394	ESP/Wet Scrubber	2	0
20d	Gas/Wood/Other Biomass/Liquid FF	All	>250	394	FF	3	0
20e	Gas/Wood/Other Biomass/Liquid FF	All	>250	394	Wet Scrubber	21	0
21a	Distillate Liquid FF	All	0-10	3	No Control	591	33
21b	Distillate Liquid FF	All	0-10	3	Cyclone	4	1
21d	Distillate Liquid FF	All	0-10	3	FF	13	2
21e	Distillate Liquid FF	All	0-10	3	Wet Scrubber	2	1
22a	Distillate Liquid FF	All	10-100	29	No Control	251	17
22b	Distillate Liquid FF	All	10-100	29	Cyclone	2	0
22c	Distillate Liquid FF	All	10-100	29	ESP	2	0
22d	Distillate Liquid FF	All	10-100	29	FF	3	0
22g	Distillate Liquid FF	All	10-100	29	Wet Scrubber	2	0
23a	Distillate Liquid FF	All	100-250	157	No Control	28	11
23b	Distillate Liquid FF	All	100-250	157	Cyclone	1	0
23d	Distillate Liquid FF	All	100-250	157	FF	1	0
23f	Distillate Liquid FF	All	100-250	157	Wet Scrubber	2	0
24a	Distillate Liquid FF	All	>250	355	No Control	20	51
24d	Distillate Liquid FF	All	>250	355	ESP	1	0
25a	NFF Liquid/NFF Solid/Gas	All	0-10	6	No Control	2	1
25b	NFF Liquid/NFF Solid/Gas	All	0-10	6	Cyclone	4	0

## Appendix E. Control Level Model Unit Parameters

Model Unit Parameters						Number Assigned	
Model No	Material Combination	Combustor Design	Capacity Range (MMBtu/hr)	Average Capacity (MMBtu/hr)	Control Level	Boilers	Process Heaters
26a	NFF Liquid/NFF Solid/Gas	All	10-100	58	No Control	23	0
26b	NFF Liquid/NFF Solid/Gas	All	10-100	58	Cyclone	8	0
26c	NFF Liquid/NFF Solid/Gas	All	10-100	58	ESP	2	0
26d	NFF Liquid/NFF Solid/Gas	All	10-100	58	FF	5	0
26e	NFF Liquid/NFF Solid/Gas	All	10-100	58	FF/SD	2	0
26f	NFF Liquid/NFF Solid/Gas	All	10-100	58	Wet Scrubber	1	0
27a	NFF Liquid/NFF Solid/Gas	All	100-250	161	No Control	15	3
27b	NFF Liquid/NFF Solid/Gas	All	100-250	161	ESP	5	0
27c	NFF Liquid/NFF Solid/Gas	All	100-250	161	ESP/Wet Scrubber	1	0
27d	NFF Liquid/NFF Solid/Gas	All	100-250	161	FF	1	0
27e	NFF Liquid/NFF Solid/Gas	All	100-250	161	Cyclone	1	0
27f	NFF Liquid/NFF Solid/Gas	All	100-250	161	Wet Scrubber	2	0
28a	NFF Liquid/NFF Solid/Gas	All	>250	562	No Control	12	0
28b	NFF Liquid/NFF Solid/Gas	All	>250	562	ESP	5	0
28c	NFF Liquid/NFF Solid/Gas	All	>250	562	Wet Scrubber	4	0
29a	Wood	Other	0-10	5	No Control	64	2
29b	Wood	Other	0-10	5	Cyclone	64	2
29c	Wood	Other	0-10	5	FF	3	0
30a	Wood	Other	10-100	30	No Control	63	2
30b	Wood	Other	10-100	30	Cyclone	223	6
30c	Wood	Other	10-100	30	ESP	10	8
30d	Wood	Other	10-100	30	FF	4	7
30e	Wood	Other	10-100	30	Wet Scrubber	23	2
31a	Wood	Other	100-250	179	No Control	2	0
31b	Wood	Other	100-250	179	Cyclone	8	0
31c	Wood	Other	100-250	179	Cyclone/Packed Scrubber	1	0
31d	Wood	Other	100-250	179	ESP	19	0
31e	Wood	Other	100-250	179	Wet Scrubber	26	0
32a	Wood	Other	>250	449	No Control	2	0
32b	Wood	Other	>250	449	Cyclone	3	0
32c	Wood	Other	>250	449	ESP	13	0
32d	Wood	Other	>250	449	Wet Scrubber	4	0
33a	Wood	Wall-fired/PC/Other	0-10	7	No Control	9	0
33b	Wood	Wall-fired/PC/Other	0-10	7	Cyclone	5	0
34a	Wood	Wall-fired/PC/Other	10-100	26	No Control	2	0
34b	Wood	Wall-fired/PC/Other	10-100	26	Cyclone	27	0
34c	Wood	Wall-fired/PC/Other	10-100	26	FF	1	0
34d	Wood	Wall-fired/PC/Other	10-100	26	Wet Scrubber	1	0
35a	Wood	Wall-fired/PC/Other	>250	677	ESP	1	0
35b	Wood	Wall-fired/PC/Other	>250	677	ESP/Wet Scrubber	1	0
36a	Wood/Other Biomass/NFF Liquid/NFF Solid	All	0-10	7	No Control	3	0
36b	Wood/Other Biomass/NFF Liquid/NFF Solid	All	0-10	7	Cyclone	2	0
36c	Wood/Other Biomass/NFF Liquid/NFF Solid	All	0-10	7	ESP	1	0
36e	Wood/Other Biomass/NFF Liquid/NFF Solid	All	0-10	7	Wet Scrubber	4	0
37a	Wood/Other Biomass/NFF Liquid/NFF Solid	All	10-100	44	No Control	3	0
37b	Wood/Other Biomass/NFF Liquid/NFF Solid	All	10-100	44	Cyclone	11	0
37c	Wood/Other Biomass/NFF Liquid/NFF Solid	All	10-100	44	Cyclone/Packed Scrubber	1	0
37d	Wood/Other Biomass/NFF Liquid/NFF Solid	All	10-100	44	ESP	3	0
37e	Wood/Other Biomass/NFF Liquid/NFF Solid	All	10-100	44	FF	6	0
37f	Wood/Other Biomass/NFF Liquid/NFF Solid	All	10-100	44	Wet Scrubber	5	0
38a	Wood/Other Biomass/NFF Liquid/NFF Solid	All	100-250	173	Cyclone	1	0
38b	Wood/Other Biomass/NFF Liquid/NFF Solid	All	100-250	173	Cyclone/Packed Scrubber	1	0
38c	Wood/Other Biomass/NFF Liquid/NFF Solid	All	100-250	173	ESP	14	0
38d	Wood/Other Biomass/NFF Liquid/NFF Solid	All	100-250	173	FF	4	0
38e	Wood/Other Biomass/NFF Liquid/NFF Solid	All	100-250	173	FF/FSI	1	0
38f	Wood/Other Biomass/NFF Liquid/NFF Solid	All	100-250	173	FF/Wet Scrubber	1	0
38g	Wood/Other Biomass/NFF Liquid/NFF Solid	All	100-250	173	Wet Scrubber	14	0
39a	Wood/Other Biomass/NFF Liquid/NFF Solid	All	>250	513	No Control	1	0
39b	Wood/Other Biomass/NFF Liquid/NFF Solid	All	>250	513	Cyclone	4	0
39c	Wood/Other Biomass/NFF Liquid/NFF Solid	All	>250	513	ESP	24	0
39e	Wood/Other Biomass/NFF Liquid/NFF Solid	All	>250	513	ESP/Wet Scrubber	1	0
39f	Wood/Other Biomass/NFF Liquid/NFF Solid	All	>250	513	FF	1	0
39g	Wood/Other Biomass/NFF Liquid/NFF Solid	All	>250	513	Wet Scrubber	31	0
40a	Residual Liquid FF	All	0-10	3	No Control	154	14
40b	Residual Liquid FF	All	0-10	3	Cyclone	1	0
40d	Residual Liquid FF	All	0-10	3	FF	3	0
41a	Residual Liquid FF	All	10-100	37	No Control	405	138

# Appendix E. Control Level Model Unit Parameters

Model Unit Parameters						Number Assigned	
Model No	Material Combination	Combustor Design	Capacity Range (MMBtu/hr)	Average Capacity (MMBtu/hr)	Control Level	Boilers	Process Heaters
41b	Residual Liquid FF	All	10-100	37	Cyclone	17	0
41c	Residual Liquid FF	All	10-100	37	ESP	0	1
41d	Residual Liquid FF	All	10-100	37	FF	13	0
41g	Residual Liquid FF	All	10-100	37	Wet Scrubber	11	1
42a	Residual Liquid FF	All	100-250	172	No Control	78	50
42b	Residual Liquid FF	All	100-250	172	Cyclone	23	0
42c	Residual Liquid FF	All	100-250	172	ESP	6	0
42d	Residual Liquid FF	All	100-250	172	FF	1	0
42e	Residual Liquid FF	All	100-250	172	Packed Scrubber	1	0
42f	Residual Liquid FF	All	100-250	172	Wet Scrubber	6	0
43a	Residual Liquid FF	All	>250	547	No Control	54	13
43b	Residual Liquid FF	All	>250	547	Cyclone	5	0
43d	Residual Liquid FF	All	>250	547	ESP	2	0
44a	Bagasse/Other	All	10-100	72	Cyclone	6	0
44b	Bagasse/Other	All	10-100	72	Wet Scrubber	17	0
45a	Bagasse/Other	All	100-250	158	No Control	1	0
45b	Bagasse/Other	All	100-250	158	Cyclone	8	0
45c	Bagasse/Other	All	100-250	158	Wet Scrubber	13	0
46a	Bagasse/Other	All	>250	419	ESP	1	0
46b	Bagasse/Other	All	>250	419	ESP/Activated Carbon Adsorption	5	0
46c	Bagasse/Other	All	>250	419	Wet Scrubber	31	0
47a	Coal	Other	0-10	4	No Control	2	0
48a	Coal	Other	10-100	54	No Control	4	0
48b	Coal	Other	10-100	54	Cyclone	22	0
48c	Coal	Other	10-100	54	ESP	1	0
48d	Coal	Other	10-100	54	FF	1	0
49b	Coal	Other	100-250	466	Cyclone	8	0
49c	Coal	Other	100-250	466	ESP	1	0
50c	Coal	Other	>250	565	ESP	3	0
50f	Coal	Other	>250	565	FF	1	0
52a	Coal	Wall-fired/PC	10-100	57	No Control	2	0
52b	Coal	Wall-fired/PC	10-100	57	Cyclone	4	0
52f	Coal	Wall-fired/PC	10-100	57	Wet Scrubber	1	0
53b	Coal	Wall-fired/PC	100-250	186	Cyclone	2	0
53d	Coal	Wall-fired/PC	100-250	186	ESP	1	0
54c	Coal	Wall-fired/PC	>250	600	ESP	5	0
55b	Coal/Wood/NFF Liquid/NFF Solid	All	0-10	6	Cyclone	1	0
56b	Coal/Wood/NFF Liquid/NFF Solid	All	10-100	35	Cyclone	2	0
57d	Coal/Wood/NFF Liquid/NFF Solid	All	100-250	173	FF	1	0
58a	Gas	Other	0-10	3	No Control	632	64
58d	Gas	Other	0-10	3	FF	5	4
58h	Gas	Other	0-10	3	Wet Scrubber	4	1
59a	Gas	Other	10-100	33	No Control	250	55
59b	Gas	Other	10-100	33	Cyclone	7	0
59d	Gas	Other	10-100	33	FF	6	0
59e	Gas	Other	10-100	33	FF/Wet Scrubber	3	0
59f	Gas	Other	10-100	33	Wet Scrubber	1	0
60a	Gas	Other	100-250	164	No Control	38	3
60b	Gas	Other	100-250	164	Cyclone	1	0
60e	Gas	Other	100-250	164	FF	1	0
61a	Gas	Other	>250	520	No Control	16	2
62a	Gas/Wood/Other Biomass/Liquid FF	All	0-10	6	No Control	1	0
62b	Gas/Wood/Other Biomass/Liquid FF	All	0-10	6	Cyclone	1	0
63a	Gas/Wood/Other Biomass/Liquid FF	All	10-100	45	No Control	1	0
63b	Gas/Wood/Other Biomass/Liquid FF	All	10-100	45	Cyclone	1	0
64d	Gas/Wood/Other Biomass/Liquid FF	All	100-250	178	ESP	1	0
64e	Gas/Wood/Other Biomass/Liquid FF	All	100-250	178	ESP/Wet Scrubber	1	0
65e	Gas/Wood/Other Biomass/Liquid FF	All	>250	394	Wet Scrubber	1	0
66a	Distillate Liquid FF	All	0-10	3	No Control	105	4
67a	Distillate Liquid FF	All	10-100	29	No Control	59	2
67d	Distillate Liquid FF	All	10-100	29	FF	1	0
68a	Distillate Liquid FF	All	100-250	157	No Control	13	0
69a	Distillate Liquid FF	All	>250	355	No Control	4	0
69d	Distillate Liquid FF	All	>250	355	ESP	1	0
70b	NFF Liquid/NFF Solid/Gas	All	10-100	58	Cyclone	1	0
72b	NFF Liquid/NFF Solid/Gas	All	>250	562	ESP	1	0

## Appendix E. Control Level Model Unit Parameters

Model Unit Parameters						Number Assigned	
Model No	Material Combination	Combustor Design	Capacity Range (MMBtu/hr)	Average Capacity (MMBtu/hr)	Control Level	Boilers	Process Heaters
73a	Wood	Other	0-10	5	No Control	5	0
73b	Wood	Other	0-10	5	Cyclone	6	0
74a	Wood	Other	10-100	30	No Control	3	0
74b	Wood	Other	10-100	30	Cyclone	1	0
74e	Wood	Other	10-100	30	Wet Scrubber	1	0
75e	Wood	Other	100-250	179	Wet Scrubber	1	0
76b	Wood	Wall-fired/PC	0-10	7	Cyclone	2	0
77b	Wood	Wall-fired/PC	10-100	26	Cyclone	1	0
78a	Wood/Other Biomass/NFF Liquid/NFF Solid	All	0-10	7	No Control	1	0
79b	Wood/Other Biomass/NFF Liquid/NFF Solid	All	10-100	44	Cyclone	2	0
79d	Wood/Other Biomass/NFF Liquid/NFF Solid	All	10-100	44	ESP	1	0
80a	Residual Liquid FF	All	0-10	3	No Control	34	2
81a	Residual Liquid FF	All	10-100	37	No Control	96	10
81g	Residual Liquid FF	All	10-100	37	Wet Scrubber	3	0
82a	Residual Liquid FF	All	100-250	172	No Control	19	0
83a	Residual Liquid FF	All	>250	547	No Control	2	0
<b>TOTAL</b>						<b>19,126</b>	<b>2,991</b>

## **Appendix F-1**

### **Assigned Units, Distributed Units, and Total Units Associated with Control Level Model Units**

(See Excel spreadsheet “ModelappD-F.xls”)



Appendix F-1. Assigned Units, Distributed Units, and Total Units Associated with Control Level Model Units

Model No	Boilers			Process Heaters		
	Number Assigned to Model	Number Distributed to Model	Total Number for Model	Number Assigned to Model	Number Distributed to Model	Total Number for Model
1a	18	30	48	0	0	0
1b	12	20	32	0	0	0
1c	1	2	3	0	0	0
2a	70	84	154	0	0	0
2b	198	238	436	0	0	0
2c	56	67	123	0	0	0
2d	82	99	181	0	0	0
2e	2	3	5	0	0	0
2f	2	3	5	0	0	0
2g	7	8	15	0	0	0
3a	22	24	46	0	0	0
3b	79	87	166	0	0	0
3c	53	59	112	0	0	0
3d	1	1	2	0	0	0
3e	76	84	160	0	0	0
3f	2	2	4	0	0	0
3g	2	2	4	0	0	0
3h	7	8	15	0	0	0
4a	12	12	24	0	0	0
4b	7	7	14	0	0	0
4c	20	20	40	0	0	0
4d	1	1	2	0	0	0
4e	2	2	4	0	0	0
4f	28	28	56	0	0	0
4g	20	20	40	0	0	0
4h	5	5	10	0	0	0
4i	3	3	6	0	0	0
4j	4	4	8	0	0	0
5a	4	6	10	0	0	0
5b	1	1	2	0	0	0
6a	6	8	14	0	0	0
6b	2	3	5	0	0	0
6c	16	21	37	0	0	0
6d	12	16	28	0	0	0
6e	1	1	2	0	0	0
6f	5	7	12	0	0	0
7a	5	7	12	0	0	0
7b	2	3	5	0	0	0
7c	2	3	5	0	0	0
7d	40	53	93	0	0	0
7e	34	45	79	0	0	0
7f	1	1	2	0	0	0
7g	1	1	2	0	0	0
7h	6	8	14	0	0	0
8a	7	10	17	0	0	0
8c	82	114	196	0	0	0
8d	2	3	5	0	0	0
8e	3	4	7	0	0	0
8f	5	7	12	0	0	0
8g	15	21	36	0	0	0
8h	5	7	12	0	0	0
8i	1	1	2	0	0	0
8j	1	1	2	0	0	0
8k	1	1	2	0	0	0
9a	2	0	2	0	0	0
9b	4	1	5	0	0	0
10a	8	0	8	0	0	0
10b	53	1	54	0	0	0
10c	5	0	5	0	0	0
11a	3	0	3	0	0	0
11b	10	1	11	0	0	0
11c	2	0	2	0	0	0
11d	2	0	2	0	0	0
12a	1	0	1	0	0	0
12b	4	0	4	0	0	0
12c	45	2	47	0	0	0
12d	1	0	1	0	0	0
12e	4	0	4	0	0	0
12f	5	0	5	0	0	0
12g	7	0	7	0	0	0
12h	2	0	2	0	0	0
12i	6	0	6	0	0	0
13a	8,016	10,453	18,469	1,425	6,843	8,268
13b	39	51	90	5	24	29
13c	4	5	9	19	91	110

Appendix F-1. Assigned Units, Distributed Units, and Total Units Associated with Control Level Model Units

Model No	Boilers			Process Heaters		
	Number Assigned to Model	Number Distributed to Model	Total Number for Model	Number Assigned to Model	Number Distributed to Model	Total Number for Model
13d	79	103	182	11	53	64
13e	2	3	5	0	0	0
13f	4	5	9	0	0	0
13g	4	5	9	0	0	0
13h	22	29	51	22	106	128
14a	4,665	5,067	9,732	691	3,303	3,994
14b	57	62	119	1	5	6
14c	11	12	23	0	0	0
14d	33	36	69	5	24	29
14e	6	7	13	0	0	0
14f	40	43	83	25	120	145
15a	487	555	1,042	168	306	474
15b	10	11	21	0	0	0
15c	8	9	17	0	0	0
15d	1	1	2	1	2	3
15e	4	5	9	0	0	0
15f	9	10	19	11	20	31
16a	224	249	473	83	93	176
16b	3	3	6	6	7	13
16c	6	7	13	0	0	0
16d	4	4	8	5	6	11
17a	9	1	10	0	0	0
17b	10	1	11	0	0	0
17c	2	0	2	0	0	0
17d	2	0	2	0	0	0
18a	11	1	12	0	0	0
18b	60	6	66	0	0	0
18c	12	1	13	0	0	0
18d	1	0	1	0	0	0
18e	1	0	1	0	0	0
18f	1	0	1	0	0	0
18g	3	0	3	0	0	0
19b	4	1	5	0	0	0
19c	1	0	1	0	0	0
19d	11	1	12	0	0	0
19e	1	0	1	0	0	0
19f	13	2	15	0	0	0
20a	4	1	5	0	0	0
20b	10	1	11	0	0	0
20c	2	0	2	0	0	0
20d	3	0	3	0	0	0
20e	21	3	24	0	0	0
21a	591	1,309	1,900	33	133	166
21b	4	9	13	1	4	5
21d	13	29	42	2	8	10
21e	2	4	6	1	4	5
22a	251	536	787	17	84	101
22b	2	4	6	0	0	0
22c	2	4	6	0	0	0
22d	3	6	9	0	0	0
22g	2	4	6	0	0	0
23a	28	50	78	11	4	15
23b	1	2	3	0	0	0
23d	1	2	3	0	0	0
23f	2	4	6	0	0	0
24a	20	33	53	51	0	51
24d	1	2	3	0	0	0
25a	2	0	2	1	3	4
25b	4	0	4	0	0	0
26a	23	6	29	0	3	3
26b	8	2	10	0	0	0
26c	2	1	3	0	0	0
26d	5	2	7	0	0	0
26e	2	1	3	0	0	0
26f	1	0	1	0	0	0
27a	15	6	21	3	1	4
27b	5	2	7	0	0	0
27c	1	0	1	0	0	0
27d	1	0	1	0	0	0
27e	1	0	1	0	0	0
27f	2	1	3	0	0	0
28a	12	1	13	0	0	0
28b	5	0	5	0	0	0
28c	4	0	4	0	0	0
29a	64	12	76	2	2	4

Appendix F-1. Assigned Units, Distributed Units, and Total Units Associated with Control Level Model Units

Model No	Boilers			Process Heaters		
	Number Assigned to Model	Number Distributed to Model	Total Number for Model	Number Assigned to Model	Number Distributed to Model	Total Number for Model
29b	64	12	76	2	2	4
29c	3	1	4	0	0	0
30a	63	10	73	2	1	3
30b	223	33	256	6	2	8
30c	10	2	12	8	3	11
30d	4	1	5	7	2	9
30e	23	3	26	2	1	3
31a	2	0	2	0	0	0
31b	8	1	9	0	0	0
31c	1	0	1	0	0	0
31d	19	2	21	0	0	0
31e	26	3	29	0	0	0
32a	2	0	2	0	0	0
32b	3	0	3	0	0	0
32c	13	1	14	0	0	0
32d	4	1	5	0	0	0
33a	9	1	10	0	0	0
33b	5	0	5	0	0	0
34a	2	0	2	0	0	0
34b	27	1	28	0	0	0
34c	1	0	1	0	0	0
34d	1	0	1	0	0	0
35a	1	0	1	0	0	0
35b	1	0	1	0	0	0
36a	3	0	3	0	0	0
36b	2	0	2	0	0	0
36c	1	0	1	0	0	0
36e	4	1	5	0	0	0
37a	3	0	3	0	0	0
37b	11	1	12	0	0	0
37c	1	0	1	0	0	0
37d	3	0	3	0	0	0
37e	6	1	7	0	0	0
37f	5	1	6	0	0	0
38a	1	0	1	0	0	0
38b	1	0	1	0	0	0
38c	14	1	15	0	0	0
38d	4	0	4	0	0	0
38e	1	0	1	0	0	0
38f	1	0	1	0	0	0
38g	14	1	15	0	0	0
39a	1	0	1	0	0	0
39b	4	0	4	0	0	0
39c	24	2	26	0	0	0
39e	1	0	1	0	0	0
39f	1	0	1	0	0	0
39g	31	2	33	0	0	0
40a	154	311	465	14	61	75
40b	1	2	3	0	0	0
40d	3	6	9	0	0	0
41a	405	643	1,048	138	370	508
41b	17	27	44	0	0	0
41c	0	0	0	1	3	4
41d	13	21	34	0	0	0
41g	11	17	28	1	3	4
42a	78	101	179	50	16	66
42b	23	30	53	0	0	0
42c	6	8	14	0	0	0
42d	1	1	2	0	0	0
42e	1	1	2	0	0	0
42f	6	8	14	0	0	0
43a	54	71	125	13	4	17
43b	5	6	11	0	0	0
43d	2	3	5	0	0	0
44a	6	3	9	0	0	0
44b	17	10	27	0	0	0
45a	1	1	2	0	0	0
45b	8	5	13	0	0	0
45c	13	8	21	0	0	0
46a	1	1	2	0	0	0
46b	5	3	8	0	0	0
46c	31	19	50	0	0	0
47a	2	34	36	0	0	0
48a	4	6	10	0	0	0
48b	22	32	54	0	0	0

Appendix F-1. Assigned Units, Distributed Units, and Total Units Associated with Control Level Model Units

Model No	Boilers			Process Heaters		
	Number Assigned to Model	Number Distributed to Model	Total Number for Model	Number Assigned to Model	Number Distributed to Model	Total Number for Model
48c	1	2	3	0	0	0
48d	1	2	3	0	0	0
49b	8	18	26	0	0	0
49c	1	2	3	0	0	0
50c	3	2	5	0	0	0
50f	1	1	2	0	0	0
52a	2	7	9	0	0	0
52b	4	14	18	0	0	0
52f	1	4	5	0	0	0
53b	2	4	6	0	0	0
53d	1	2	3	0	0	0
54c	5	10	15	0	0	0
55b	1	0	1	0	0	0
56b	2	0	2	0	0	0
57d	1	0	1	0	0	0
58a	632	956	1,588	64	286	350
58d	5	8	13	4	18	22
58h	4	6	10	1	5	6
59a	250	311	561	55	165	220
59b	7	9	16	0	0	0
59d	6	7	13	0	0	0
59e	3	4	7	0	0	0
59f	1	1	2	0	0	0
60a	38	36	74	3	9	12
60b	1	1	2	0	0	0
60e	1	1	2	0	0	0
61a	16	10	26	2	12	14
62a	1	0	1	0	0	0
62b	1	0	1	0	0	0
63a	1	1	2	0	0	0
63b	1	0	1	0	0	0
64d	1	0	1	0	0	0
64e	1	0	1	0	0	0
65e	1	0	1	0	0	0
66a	105	302	407	4	17	21
67a	59	148	207	2	6	8
67d	1	2	3	0	0	0
68a	13	29	42	0	1	1
69a	4	6	10	0	1	1
69d	1	2	3	0	0	0
70b	1	2	3	0	1	1
72b	1	0	1	0	0	0
73a	5	1	6	0	0	0
73b	6	2	8	0	0	0
74a	3	1	4	0	0	0
74b	1	1	2	0	0	0
74e	1	1	2	0	0	0
75e	1	0	1	0	0	0
76b	2	1	3	0	0	0
77b	1	1	2	0	0	0
78a	1	1	2	0	0	0
79b	2	1	3	0	0	0
79d	1	0	1	0	0	0
80a	34	125	159	2	6	8
81a	96	199	295	10	13	23
81g	3	6	9	0	0	0
82a	19	44	63	0	0	0
83a	2	5	7	0	0	0
<b>TOTAL</b>	<b>19,126</b>	<b>23,826</b>	<b>42,952</b>	<b>2,991</b>	<b>12,257</b>	<b>15,248</b>

## **Appendix F-2**

### **Assigned Units, Distributed Units, and Total Units Associated with Control Level Model Units - Summed per General Model Units**

(See Excel spreadsheet "ModelappD-F.xls")

**Appendix F-2. Assigned Units, Distributed Units, and Total Units Associated with  
Control Level Model Units - Summed per General Model Units**

Model No	Boilers			Process Heaters		
	Number Assigned to Model	Number Distributed to Model	Total Number for Model	Number Assigned to Model	Number Distributed to Model	Total Number for Model
1	31	52	83	0	0	0
2	417	502	919	0	0	0
3	242	267	509	0	0	0
4	102	102	204	0	0	0
5	5	7	12	0	0	0
6	42	56	98	0	0	0
7	91	121	212	0	0	0
8	122	169	291	0	0	0
9	6	1	7	0	0	0
10	66	1	67	0	0	0
11	17	1	18	0	0	0
12	75	2	77	0	0	0
13	8,170	10,654	18,824	1,482	7,117	8,599
14	4,812	5,227	10,039	722	3,452	4,174
15	519	591	1,110	180	328	508
16	237	263	500	94	106	200
17	23	2	25	0	0	0
18	89	8	97	0	0	0
19	30	4	34	0	0	0
20	40	5	45	0	0	0
21	610	1,351	1,961	37	149	186
22	260	554	814	17	84	101
23	32	58	90	11	4	15
24	21	35	56	51	0	51
25	6	0	6	1	3	4
26	41	12	53	0	3	3
27	25	9	34	3	1	4
28	21	1	22	0	0	0
29	131	25	156	4	4	8
30	323	49	372	25	9	34
31	56	6	62	0	0	0
32	22	2	24	0	0	0
33	14	1	15	0	0	0
34	31	1	32	0	0	0
35	2	0	2	0	0	0
36	10	1	11	0	0	0
37	29	3	32	0	0	0
38	36	2	38	0	0	0
39	62	4	66	0	0	0
40	158	319	477	14	61	75
41	446	708	1,154	140	376	516
42	115	149	264	50	16	66
43	61	80	141	13	4	17
44	23	13	36	0	0	0
45	22	14	36	0	0	0
46	37	23	60	0	0	0
47	2	34	36	0	0	0
48	28	42	70	0	0	0
49	9	20	29	0	0	0
50	4	3	7	0	0	0

**Appendix F-2. Assigned Units, Distributed Units, and Total Units Associated with  
Control Level Model Units - Summed per General Model Units**

Model No	Boilers			Process Heaters		
	Number Assigned to Model	Number Distributed to Model	Total Number for Model	Number Assigned to Model	Number Distributed to Model	Total Number for Model
52	7	25	32	0	0	0
53	3	6	9	0	0	0
54	5	10	15	0	0	0
55	1	0	1	0	0	0
56	2	0	2	0	0	0
57	1	0	1	0	0	0
58	641	970	1,611	69	309	378
59	267	332	599	55	165	220
60	40	38	78	3	9	12
61	16	10	26	2	12	14
62	2	0	2	0	0	0
63	2	1	3	0	0	0
64	2	0	2	0	0	0
65	1	0	1	0	0	0
66	105	302	407	4	17	21
67	60	150	210	2	6	8
68	13	29	42	0	1	1
69	5	8	13	0	1	1
70	1	2	3	0	1	1
72	1	0	1	0	0	0
73	11	3	14	0	0	0
74	5	3	8	0	0	0
75	1	0	1	0	0	0
76	2	1	3	0	0	0
77	1	1	2	0	0	0
78	1	1	2	0	0	0
79	3	1	4	0	0	0
80	34	125	159	2	6	8
81	99	205	304	10	13	23
82	19	44	63	0	0	0
83	2	5	7	0	0	0
<b>TOTAL</b>	<b>19,126</b>	<b>23,826</b>	<b>42,952</b>	<b>2,991</b>	<b>12,257</b>	<b>15,248</b>



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